

ADAPTIVE SOCIAL RESPONSE IN COUPLED SOCIAL-ECOLOGICAL SYSTEMS:  
AGRICULTURE AND HYPOXIA IN THE GULF OF MEXICO

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This dissertation provides definitions and tests mechanisms of adaptive social response, an important concept in sustainability studies, based on the premise that the recognition of ecological risks, such as excess nitrogen, should lead to an adaptive social response in the form of resource investments that can be analyzed, understood and improved through interdisciplinary scholarly research. The specific assumptions are tested in the case of the “dead zone” in the Gulf of Mexico. The dead zone is a low-oxygen or hypoxic zone that is primarily caused by nitrogen fertilizers leaching from farm fields in the far-away upper reaches of the Mississippi River Basin (MRB). Based on semi-structured interviews with 40 organizations working in the MRB farming sector, I recorded and analyzed data on organizational demographics, cognitive orientation, resource investments, and organizational programs. Disaggregating findings by space and time shows that responses at all levels of social organization, nation, state, and organizational fields are poorly targeted, weakly ecological, and often outright symbolic, created to meet legitimacy challenges, not environmental goals. Furthermore, the stress that learning in existing organizations is difficult and incomplete.

Concepts that can serve to understand social-ecological processes in more than one setting such as the social-ecological interface, targeting, proximity or organizational age need to be evaluated and interpreted in individual cases but are sufficiently flexible to generate explanations for a broad range of cases and topics. As such, can help to ascertain what constrains and enables adaptation

to sustainability demands. This dissertation complements research on individual agency and individual as well as organizational learning by pointing out the systemic effects that are at work at the level of constellations of organizations joined by shared representations, geographical regions, or time of founding. As such it broadens the scope of analysis to overcome current limitations of research, management and policy focused more narrowly on individual and organizational learning in response to ecological risks.

## BIOGRAPHICAL SKETCH

Stefanie Hufnagl-Eichiner was born in Regensburg, Germany on October 4<sup>th</sup>, 1976 to Hildegard and Hans Hufnagl. She grew up in Neuburg am Inn in the Landkreis Passau, here she went to primary school and the Maristengymnasium Fürstenzell. She was active in her church parish as youth group leader and parish council member. She received a MS in forest sciences (Diplom Forstwirt Univ.) from the Technische Universität München in 2002 with partial credit from study-abroad programs at the Yale School of Forestry and Bogor Agricultural Institute. Stefanie Hufnagl-Eichiner worked as research assistant for the Bavarian State Institute of Forestry in 2002 and 2003 and as a research assistant at the Department of Natural Resources, Cornell University in 2004 and 2005. Since 2005 Stefanie is working on her Doctorate in Natural Resources Policy and Management at Cornell University. Stefanie is married to Florian Bernhard Eichiner and is the mother of Florian Eichiner and Sofie Eichiner.

Für meine Eltern Hildegard und Hans Hufnagl.

Für meine Lehrer Elfriede Köppel, Gunther Willeitner, und Jennifer Osha.

Und für meine Familie, ohne die ich diese Arbeit weder begonnen noch beendet hätte:

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## TABLE OF CONTENTS

Bibliographical sketch	iii
Dedication	iv
Acknowledgments	v
Table of Contents	vi
Preface	vii
CHAPTER 1 INTRODUCTION	1
CHAPTER 2 ASSESSING SOCIAL-ECOLOGICAL COUPLING: AGRICULTURE AND HYPOXIA IN THE GULF OF MEXICO	11
Article published in Global Environmental Change together with Steven A. Wolf and Laurie E. Drinkwater	
CHAPTER 3 ORGANIZATIONAL ADAPTATION TO NEW ENVIRONMENTAL DEMANDS: IN SEARCH OF PROXIMITY EFFECTS IN THE MISSISSIPPI RIVER BASIN	47
A future version of this chapter will be published together with Steven A. Wolf	
CHAPTER 4 LIMITS TO LEARNING: UNDERSTANDING OPPORTUNITIES AND CONSTRAINTS FOR AGRO-ECOLOGICAL REFORM IN THE MISSISSIPPI RIVER BASIN THROUGH ORGANIZATIONAL ECOLOGY	82
Under review at Society and Natural Resources	
CHAPTER 5 SYNTHESIS	108
APPENDIX INTERVIEW GUIDE	116



## PREFACE

Wise apprentices always recognize that the masters are always part of them, that within them is a partnership of apprentice and master artisan, including all the other masters that came before. Good apprentices know that they are in the process of becoming masters and that as responsible artisans they must seek to improve upon the knowledge entrusted to them and go further.

William S. Coperthwaite

To know and not to do is not to know.

Wang Yang Ming

## CHAPTER 1

### INTRODUCTION

#### **Concepts of adaptive social response**

Adaptive social response is an important concept in sustainability studies (Becker et al. 1999; Folke et al. 2002; Armitage et al. 2008). Sustainability studies aim at sustaining and improving living conditions for human populations by analyzing and optimizing the feedback that occurs between social and biophysical system components (Norgaard 1994). Therefore, sustainability studies often support a normative research agenda (Gladwin et al. 1995; Becker et al. 1999). Within such an agenda, we consider a social response that leads to environmental or socioeconomic degradation as maladaptive. By contrast, adaptive behavior describes social responses that reduce environmental degradation (Hufnagel-Eichiner et al. 2011). A theory of adaptive social response requires specification of the mechanisms that link institutional pressures and organizational outputs, and the variables that mediate these linkages. This dissertation introduces frameworks with which to conceptualize these mechanisms and variables, and test their applicability in the case of the “dead zone” in the Gulf of Mexico. The dead zone is a low-oxygen or hypoxic zone that is primarily caused by nitrogen fertilizers leaching from farm fields in the far-away upper reaches of the Mississippi River Basin (MRB) (EWG 2006; USEPA 2008). This dissertation evaluates the utility of the concepts chosen in recognizing opportunities and obstacles for supporting society-level sustainability transitions in organizations, sectors and territories.

#### *The organizational field as a level of analysis*

To understand social response to ecological challenges, the majority of studies use approaches that can be considered microeconomic and behaviorist in orientation. They are reductionist in that they postulate that complex social outcomes can be reduced to the aggregate behavior of individual actors, as well as the direct control regulation exerts over them. In the case of water pollution, for example, they assume that farming practices are implemented at the farm level and aim to put in place incentives and regulations that shape the

behavior of individual farmers. However, farmers do not operate in a vacuum: Much of the individual farmers' activity is based on know-how that, rather than being produced or even producible by individuals, is accessed in interaction with a number of groups and organizations (Savage 1994; Wolf 2008, Moore 2008). Rather, broader economic, social, institutional and cultural factors drive farmer decisions and practices. Taking this embeddedness of individual action into account, institutional theory postulates that complex social outcomes cannot be reduced to the characteristics or motives of individual actors, but are always shaped by broader cultural forces that act on individuals at the level of industries, organizational fields or nation states (Schneiberg and Clemens 2006). Thus, to better understand social response to environmental threats beyond the individual, processes not at the individual level, but at the broader levels of federal policy and research (chapter 2), individual states (chapter 3), and organizational fields (chapter 4), in which individual action is embedded need to be researched.

*Resource allocation: Material expressions of social response*

Shifting institutional demands, such as increased social and political pressure to address environmental problems, force social actors at all levels of social organization to deal with the real-world challenges of translating these changed demands into concrete behavior. Few studies attend to what lies between multiple and layered institutional pressures and social outputs, namely, the material resource investments made to meet demands for environmental protection (Wolf and Primmer 2006). What kinds of resources are allocated, and in what amount? How do these resources translate into ecological improvements? What conditions can facilitate the actual transition to more sustainable societies? To further a research agenda on the role of material resource investments and environmental outputs, this dissertation extends the work of Wolf and Primmer (2006) and Primmer and Wolf (2009) and aims to answer the following questions: What kinds of resources do social actors invest in efforts to improve environmental conditions in the Gulf of Mexico, and in what amount (chapters 2 and 3)? What explains the variation in resource allocation (chapters 3 and 4)? Finally, how do the resources invested map onto environmental outputs (chapters 3 and 4)?

**Excess nitrogen as a major threat to the well-being of human populations**

The last ten thousand years on Earth have been remarkably stable with respect to temperatures, freshwater availability and biogeochemical flows, allowing human populations to grow and develop at previously unattained rates (Rioual et al 2001; Crutzen 2002). Rockström et al. (2009) define planetary thresholds for seven parameters ranging from freshwater use to climate change which, if overstepped, could tip these relatively stable conditions with dire implications for human well-being. With regard to the nitrogen cycle, Rockström et al. (2009) claim that these thresholds have been overstepped already.

The use of fossil fuels to convert atmospheric nitrogen into plant-available form has facilitated previously impossible rates of food production, and human population growth has been correspondingly high. Nitrogen used as fertilizer, in combination with nitrogen released through land-use change and combustion of fossil fuels, has in many settings led from previous scarcity of nitrogen pollution (Vitousek et al. 1997). Excess nitrogen in soil, water and the atmosphere is directly linked to detrimental human health effects, as well as to socioeconomic and ecological degradation (Turner et al. 1998; Zimmerman and Nance 2001; Townsend et al. 2003; Oguz and Gilbert 2007). The “dead zone” in the Gulf of Mexico is the poster child of excess nitrogen pollution. This low-oxygen or hypoxic zone in the Gulf is primarily caused by nitrogen fertilizers leaching from farm fields in the far-away upper reaches of the Mississippi River Basin (MRB) (EWG 2006; USEPA 2008). This dissertation is motivated by the assumption that the recognition of current and future risks associated with excess nitrogen, in combination with an increased overall awareness of the ecological risks, should lead to a meaningful and adaptive social response that can be analyzed, understood, and improved through interdisciplinary research.

#### *A definition of adaptive response*

In the case of the Mississippi River Basin, interactions that occur between social and biophysical system components at multiple spatial and temporal scales have led to environmental and socioeconomic degradation; I therefore consider them inadequate or maladaptive feedbacks. The lack of potent social and technical response to the risks of doubling of the mobile nitrogen in the global ecosystem is a prominent example of dysfunctional social-ecological feedbacks (Galloway and Cowling 2002). In contrast, adaptive

coupling occurs when linkages between the environmental and social subsystems support societal responses that prevent environmental degradation and maintain the integrity of the biosphere.

Throughout the chapters of this dissertation, emphasis is given to the treatment of prevention-orientated farming practices—in the sense of preventing reactive nitrogen to enter the farm field—in the studied organizations. Prevention-oriented practices can be considered efforts to radically restructure the MRB farming sector within the studied organizations. Many theories conceptualizing ecological risks and remedies consider radical transformation rather than step-wise improvements critical to sustainability and therefore emphasize system redesign over amendments to existing systems. Industrial ecology and ecological modernization theory emphasize design and life-cycle assessment, which consider production systems with the end in mind. That is, they aim for prevention of ecological degradation before it occurs (Mol and Sonnenfeld 2000; Scolow et al. 2006) In the sustainable management literature, MacRae et al. (1990) consider end-of-the-pipe and fertilizer efficiency approaches in agriculture as “low sustainability” approaches that will not be able to shift farming conditions sufficiently to halt or even reduce ecological destruction. In the literature on transition management, Loorbach (2007) argues that current problem-solving strategies tend to be short-term and incremental, focused on optimizing existing systems rather than on creating new ones. Loorbach draws an analogy between step-wise improvements and the kind of old thinking Einstein refers to when he noted that “we can’t solve problems by using the same kind of thinking we used when we created them.”

Persistence of Gulf hypoxia suggests a lack of investments in preventative practices in the landscape that might stem from the perceived costs and risks associated with employing them to produce acceptable yields under diverse biophysical, climatic, social and economic conditions. When the detrimental social, ecological, and economic consequences of Gulf hypoxia as an isolated problem are contrasted with the social and economic benefits that high-input (e.g. of mobile nitrogen) industrial farming provides, the need for intervention might be doubtful. However, the perceived risk might be overstated. For example, Tonitto et al (2006) actually looked at yield consequences for combining cover crops with fertilizer and did not find a yield

reduction. Having said this, “many prevention oriented practices require significant modifications of farming systems and cannot be tested or implemented with small, incremental steps.” (Drinkwater, personal communication). Bold trial spaces, not wholesale application of untested practices, could therefore be a way forward and this research sets out to look for such spaces .

Gulf hypoxia is but one manifestation of the problem of excess nitrogen and disrupted global nutrient cycles. It is therefore exemplary of a suite of environmental problems to which scholars in the fields of ecological modernization, industrial ecology, transition management, sustainable management, resilience and coupled systems have proposed and begun in earnest to study and discuss “high sustainability” (MacRae et al. 1990) solutions in the realm of prevention-orientation and radical system re-design. Responses to the specific problem of Gulf hypoxia can therefore serve to illustrate the nature and extent of social response to the broader challenge of anthropogenically altered global biophysical parameters.

## **Overview of the dissertation and its goals**

### *Coupled systems research*

In testing claims about social-ecological response processes, this dissertation aims to contribute to the study of sustainability and global environmental change. The concept of coupled social and ecological systems elides the rigid separation that emerges from consideration of humans as outside of nature (Cronon 1996). However, the analytical concept needs to be better operationalized in order to advance the field (Spaargaren, Mol and Buttel 2006; Liu et al. 2007). Such efforts will be based on collaborations between social and natural scientists that take us “beyond natural science research in which human actions are treated as exogenous or largely ignored, and social science research that fails to consider the impact of biophysical forces” (Kotchen and Young 2007: 151). Chapter 2 of this dissertation is a particularly good example of such collaboration; however, all chapters rely on concepts derived from the social and ecological sciences. For example, chapters 2 and 3 use a typology of technical procedures organizations might adopt in response to Gulf hypoxia that is derived from an agro-ecological critique of the current farming system; in addition, chapter 4 uses concepts from organizational ecology, a strand of social science that analyzes organizational processes using concepts

from evolutionary biology.

#### *Geographic effects: Disproportionality and proximity*

As the ecological is place-based, so, too, are organizations—even in a global economy. Keeping geography central in analysis therefore allows one to close the “disproportionality gap”; that is, the assumption that pollution is produced, distributed, and mitigated equally across the landscape and social actors and can be remedied by shotgun approaches. Rather, in many cases, pollution is produced in disproportionately small areas of a large polluted area, or vulnerability to pollution varies between areas. In such cases, an approach taking into account geography is indispensable. Research, policy and management need to be open to the role played by disproportionality and proximity in the production and remediation of environmental problems. Disproportionality refers to the disproportional vulnerability of landscapes to produce and suffer from environmental pollution (Nowak et al 1996). For example, the application of highly mobile nitrate fertilizers is commonplace in industrial agriculture, but the loss of large portions of nitrogen does not automatically occur wherever it is applied. For instance, land that has been drained using underground drainage pipes, referred to as “tiles”, is prone to losses at levels far exceeding those from non-tiled land (David et al. 2010). Proximity refers to another geographical effect, namely, that distance to a site of pollution plays a role in remediative efforts. For example, investments in research near sites of pollution might be ill-targeted, considering the adaptiveness of social response, if pollution is caused elsewhere. Chapters 2 and 3 pay special attention to geography and targeting of social response.

#### *Cumulative research*

In order to present a tool for management and policy and to support public debate, we need to know if and how social-ecological adaptation is manifested in particular settings at particular spatial and temporal scales, and how ecological and institutional environments constrain and enable adaptive coupling. On the other hand, such study ideally identifies and operationalizes variables “that are expected to exert an influence in more than one setting” (Freudenburg and Gramling 1994:5), contributing to the accumulation of knowledge in what is known as “mid-range sociology”. Therefore, this dissertation pays attention to geographical and

cognitive-cultural variation among actors in a sector in order to assess the role that these factors have as mitigating variables in the allocation of resources for environmental protection. As such, this dissertation considers key variables in shaping social response at the federal, state, and organizational level in specific settings, that can be compared and allow for generalization. To this end, this dissertation goes beyond a mere “mapping from the distance”, as found in much of the research on ecological modernization that entails little more than the reading of organizational/state missions and goals and the counting of environmental programs listed. Rather, in this dissertation the basis of assessment is an in-depth and in-situ engagement of the actual resources allocated in order to flesh out missions and programs. As such, this work constitutes an attempt to contribute to the kind of grounded inquiry necessary to understand real-world behavior of social actors vis-à-vis their own and broader social goals.

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## CHAPTER 2

### ASSESSING SOCIAL-ECOLOGICAL COUPLING: AGRICULTURE AND HYPOXIA IN THE GULF OF MEXICO

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#### *Abstract*

Analysis and enhancement of "coupling" of social-ecological systems (SES) has emerged as a leading theme in sustainability studies. However, as an analytical concept that can support empirical research, coupling has not been adequately developed. This study synthesizes concepts from environmental sociology and ecological sciences to derive three criteria to assess adaptive coupling of an SES: prevention orientation, spatial targeting and temporal targeting. We apply our criteria to the case of nitrogen pollution from agriculture in the Mississippi River Basin (MRB) and resulting hypoxia in the Gulf of Mexico. We analyzed the federal agricultural research and development portfolio to assess the character of investments in knowledge creation and how patterns of investment have changed over time. While superficial assessment of the data suggest that

public spending on nitrogen-relevant research constitutes a substantive response to the problem of Gulf hypoxia, disaggregating the data highlights an ineffectual response. Specifically, we find that spatial and temporal targeting of investment of socioeconomic resources in the MRB is poorly aligned with the nature of ecological risks confronting the region. In addition to this policy relevant result, our study highlights the importance of geographically referenced data and attention to relevant scales of analysis. Further, the paper demonstrates opportunities to advance concepts and empirical understanding of social-ecological coupling through interdisciplinary research on interfaces that mediate interactions in SES, for example publicly funded research aimed at agricultural practice and environmental conservation in the MRB.

## ***1 Introduction***

Analysis and enhancement of “coupling” of human and biophysical systems has emerged as a leading theme in the study of global environmental change. We find the concept of coupled social and ecological systems promising in that it allows us to elide the rigid separation that emerges from consideration of humans as outside of nature (Cronon 1996). But as an analytical concept that can support empirical research, the concept has not been adequately developed (Spaargaren, Mol and Buttel 2006). There is a need to operationalize theories of social-ecological coupling in order to advance the field (Liu et al. 2007) and base this operationalization on shared frameworks that allow for the accumulation of knowledge from different disciplines (Ostrom 2009).

A defining feature of a coupled system is the interactions that occur between social and biophysical components at multiple spatial and temporal scales (Norgaard 1994). If feedback loops between subsystems lead to environmental or socioeconomic degradation, or if there are inadequate feedbacks, we consider this to be a case of maladaptive coupling. For example, using fossil fuels to convert atmospheric nitrogen to plant-available forms has enabled previously impossible rates of food production and corresponding growth of human population. In many settings, previous scarcity of nitrogen has given way to nitrogen pollution (Vitousek et al. 1997). Excess nitrogen in soil, water, and the atmosphere is directly linked to detrimental human health effects, as well as to socioeconomic and ecological degradation (Turner et al. 1998;

Zimmerman and Nance 2001; Townsend et al. 2003; Oguz and Gilbert 2007). The lack of potent social and technical response to the risks of doubling of the mobile nitrogen in the global ecosystem is a prominent example of dysfunctional social-ecological feedbacks (Galloway and Cowling 2002). In contrast, adaptive coupling occurs when linkages between the environmental and social subsystems support societal responses that prevent environmental degradation and maintain the integrity of the biosphere.

This paper integrates the perspectives of natural and social scientists to study a specific coupled system. The goal of this study is to derive criteria to assess the *adaptive coupling* of social and ecological systems and test the applicability of these criteria in the case of the farming system of the Mississippi River Basin (MRB). We pursue this goal by introducing our empirical case and then discussing the prerequisites of adaptive coupling – general patterns of recognition and response at the interface between the social and ecological systems. We then draw on relevant social science and environmental management literatures to identify generally applicable criteria of adaptive coupling from which we derive our hypotheses. We apply these hypotheses to the case of agriculture and hypoxia in the Gulf of Mexico. We assess adaptive coupling of the social-ecological system through the analysis of eight years of federal investments in agricultural research and development in the MRB. Finally, we discuss our results to address the usefulness and limitations of measures of adaptive coupling.

## ***2 The Mississippi River Basin (MRB) as a coupled system***

Socioeconomic and ecological dynamics in the MRB are governed by a multitude of poorly understood processes and reflect well documented, long standing problems of industrialized agriculture (e.g., NRC 1993). The Mississippi River (MR) drains an expansive area of former prairie ecosystems, which has been transformed into one of the major grain baskets of the world, often referred to as the Corn Belt. The region delivers water to the Gulf of Mexico where an area of decreased oxygen (a hypoxic zone) has developed every summer for the past several decades. In the Gulf, hypoxia has altered marine ecosystem structure (USNRCS 2010) and functioning (NSTC 2000) to a point where only “limited recovery following abatement of oxygen stress” is possible.” (Rabalais, Turner, and Wiseman 2001:327). Hypoxia is caused primarily by excess

nitrogen which acts as a fertilizer of marine algae. An algal bloom occurs, and as the algae complete their life cycle and die, they sink to the seabed where they are decomposed by bacteria who consume oxygen in the process. Because the water column is stratified, the cold dense water near the bottom is cut off from the upper layers so oxygen is not replenished as rapidly as it is consumed by this burst of decomposition. The concentration of oxygen then falls to levels that are too low to support life.

The overwhelming scientific evidence points to relatively small geographic areas of intense agricultural production in the upper reaches of the Mississippi River Basin as the primary source of the pollutants, primarily nitrogen (USEPA 2008; David, Drinkwater, and McIsaac 2010). The majority of nitrogen lost from farm fields in the MRB, **about 80 percent**, stems from the Corn Belt (EWG 2006; David, Drinkwater and McIsaac 2010). Addressing land use and the technical basis of fertility management and associated incentive structure in agriculture in order to reduce nitrogen loss these upper Midwest sub-basins is, therefore, critical to reducing nitrogen loading in the Gulf of Mexico (Diaz and Rosenberg 2008; USEPA 2008; USNRCS 2010). Policy responses to the problem include the creation of the USEPA-led Mississippi River/Gulf of Mexico Watershed Nutrient Task Force in 1997 and subsequent reports in 2001 and 2008, the Congressional Hypoxia Research and Control Act of 1998 and the mobilization of a range of grassroots and national non-governmental organizations.

Use of inorganic fertilizers, combined with other modifications to crop rotations and farming systems, has “uncoupled” carbon and nitrogen cycling and contributed significantly to making agriculture the leading source of non-point source pollution in the United States (Woodmansee 1984; Galloway and Cowling 2002). Donner (2003) and Randall et al. (1997) have shown that conventional modes of continuous corn production lead to the greatest amount of nitrogen loss per acre. On average, 45 to 55 percent of nitrogen applied to corn fields in the form of inorganic fertilizer is lost to the environment within the growing season (Galloway and Cowling 2002). In this context, the challenge of efficient nitrogen fertilizer management in conventional, industrialized agriculture has been defined in terms of rationalization; how, when and where to apply these highly mobile forms of nitrogen in order to mitigate losses to the environment. The dominant response in the

domains of agricultural research and practice has been eco-efficiency-oriented fertilizer management; efforts to make outcomes “less bad” (Wolf and Buttel 1996).

In contrast, when biological processes dominate agroecosystems, carbon and nitrogen cycle together through photosynthesis, decomposition, and microbially mediated transformations of nitrogen (e.g., ammonification, denitrification). Management practices that help to re-couple carbon and nitrogen cycles include reducing the length of periods without ground cover (e.g., planting winter cover crops), returning crop residues to the soil, increased reliance on biological nitrogen fixation, and increasing perennial crops (e.g., forage legumes and grasses, woody species and perennial grains and vegetables) (Drinkwater and Snapp 2007). The effectiveness of coupling carbon and nitrogen cycles is well documented from the point of view of pollution prevention and agricultural productivity (Aber et al. 1998; Clark et al. 1998; Drinkwater, Wagoner and Sarrantonio 1998; Gardner and Drinkwater 2009). Re-coupling of carbon and nitrogen in agriculture is regarded as an avenue through which the negative impacts of farming on the environment could be curbed (Drinkwater and Snapp 2007). To realize such a significant change in a highly structured industry such as agriculture demands acknowledgment of problems and investments in alternative practices.

## **2.2 The interface between the social and the ecological sphere**

In pursuing an analysis of social and ecological systems, Kotchen and Young (2007) stress that “identifying key linkages and specifying the mechanisms that generate feedbacks pose formidable challenges” (p. 149). In order to address these challenges, Fischer-Kowalski and Haberl (2007) provide a schematic overview of the interplay between the natural and the cultural and argue that “interactions between nature and culture can only occur via ... societal ecological structures” (Fischer-Kowalski and Haberl 2007:12). (Figure 1).



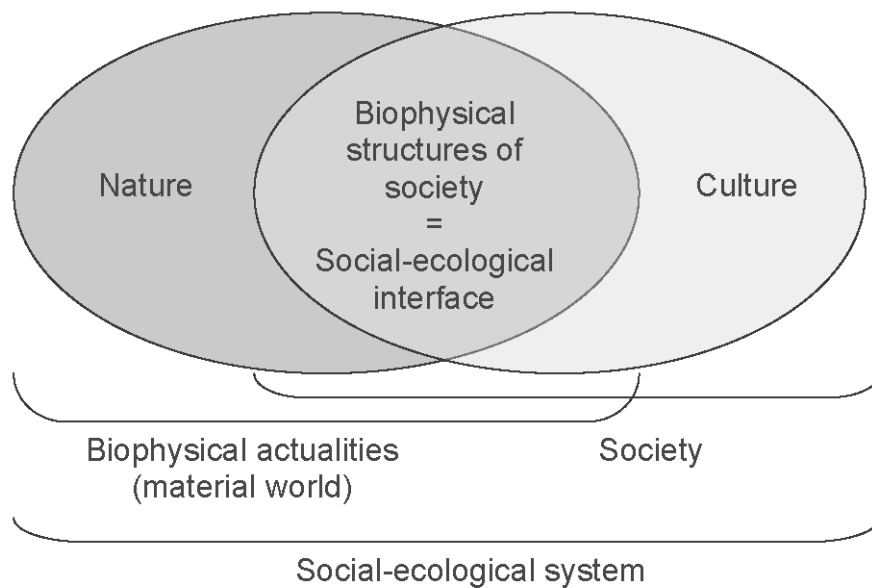


Figure 1 Biophysical structures of society as an interface in social-ecological systems. Knowledge, technology and political-economic relations are critical factors shaping this interface (Adapted from Haberl et al. 2004 in Fischer-Kowalski and Haberl 2007).

In making sense of the very general notion of societal ecological structures and as part of our effort to conduct empirical analysis of social-ecological linkages that have the potential to affect progressive change, we rely on the concept of *interface*. An interface is part of both ecological and sociocultural subsystems and is a boundary between them. Interfaces mediate flows of material and information, thereby enabling and constraining processes of co-evolution (See also Mol and Spaargaren 2006). Interfaces are shaped by governance processes (Kotchen and Young 2007) by resource allocating institutions such as governments, markets and cooperatives of various sorts.

We consider agricultural practice – additions, removals and manipulation of components of ecosystems by humans for agricultural purposes – to be the primary interface mediating flows between the ecological and the social subsystems relevant to our study. Factors shaping this dynamic interface affect the interplay between social and ecological subsystems, including nitrogen cycling, ecological integrity and human welfare. Knowledge, and, by extension, technology, are principle factors of interest.

Technological changes in agricultural practice have been relentless and transformative in the past 75 years. Agriculture is a knowledge- and science-based endeavor (Cochrane 1993). The modernization of agriculture in the U.S. has been a state project premised on the institutionalization of a scientific and educational establishment (Marcus 1985) and a rationalization of farming systems (Wolf and Wood 1997). The types of research that are conducted influence the types of knowledge, technology and farming practices that are deemed legitimate and which are profitable (Hightower 1978; Friedland, Barton and Thomas 1981). Without adopting a deterministic, linear model of technical change (Rosenberg 1982), we can say that investments in research are critical inputs shaping technical practice and developmental trajectory. While perhaps less dominant than in previous eras due to expanded commercial investments in agricultural research and development and local and regional knowledge networks, publicly funded research and extension remain essential components of agriculture in the U.S. (Wolf and Zilberman 2001). Investments in agricultural knowledge production powerfully shape agricultural practice, the social-ecological interface of interest here.

### *3 Deriving hypotheses to assess adaptive coupling*

In order to assess adaptive coupling we must operationalize the concept. We first identify generic assessment criteria, and then we operationalize these criteria by deriving specific hypotheses to structure our analysis of farming in the MRB.

In our reading of relevant bodies of literature on coupled social and ecological systems we do not find guidance as to specific criteria for assessing the nature or degree of adaptive coupling. We do, however, find common themes bridging current schools of thought on adaptive systems theories increasingly referenced through the concepts coupled systems (Young et al. 2006), resilience (Gunderson and Holling 2002) and ecological modernization (Mol and Sonnenfeld 2000). Synthesis of these distinct yet allied literatures allows us to derive a set of analytic criteria for empirically assessing adaptive coupling. The three cross-cutting criteria we identify are prevention orientation, spatial targeting, and temporal targeting.

### **3.1 Prevention orientation**

Prevention orientation is an alternative to reactive approaches to management and problem solving. Coupled systems exhibit prevention-oriented strategies when they anticipate and mitigate or avoid environmental problems rather than responding after a problem has occurred. Investments in pollution prevention are seen as cost effective. Anticipatory approaches have been identified by Mol and Sonnenfeld (2000) as reflecting society's embrace of a changing role for science and technology; movement away from a focus on servicing immediate socioeconomic needs toward a focus that takes into account our dependency on ecological integrity. Successful prevention strategies also speak to a much-repeated theme in sustainability studies, that of a system's ability to learn (Carpenter et al. 2001; Ericksen 2008). If the MRB is an adaptively coupled system, we hypothesize this will be reflected in higher investments in farming practices which prevent root causes rather than treating symptoms of nitrogen pollution (H1). For example, rather than focus on how to efficiently remediate pollution from farm fields and sub-watersheds, a prevention-oriented approach pursues pollution prevention through radical re-envisioning of the ends and means in question.

### **3.2 Spatial targeting**

Spatial targeting is an essential element of the rationalization of responses to environmental change. Spatial targeting recognizes the heterogeneity of ecological systems and competition for socioeconomic resources and on this basis focuses investments and interventions to the locations where they will most effectively mitigate environmental risks. Spatial targeting implies mobilization of local institutions (Jodha 1995), as well as mobilization of overarching institutions that are spatially removed and operate at a higher level of social organizational (Folke et al. 1998). Folke et al. (1998) stress that an institution does not have to operate at the same spatial scale as the resource of concern in order to be relevant, in fact, "broader institutions are not only politically and economically probable, but ... they may be able to negotiate a better fit to broader and slower ecological attributes of the system as well" (Folke et al. 1998:24).

If the MRB is an adaptively coupled system, we hypothesize that agricultural research investments are geographically targeted toward the Corn Belt, the pollution source area (H2.1). We note that allocating

investments to the Gulf States, the pollution sink area, would indicate a linkage between being subject to pollution and taking remedial action. But such a linkage would not constitute spatial targeting or adaptive coupling because changing farming systems and pollution rates in lower reaches of the MRB will not solve the problem of hypoxia as the majority of N lost from farm fields in the MRB stems from the upper reaches (Rabalais, Turner and Scavia 2002). Since funding alone is not indicative of adaptive coupling, we further hypothesize that an adaptively coupled MRB would exhibit greater orientation towards prevention where it matters most for pollution mitigation, that is in the Corn Belt (H2.2).

### **3.3 Temporal targeting**

Temporal targeting refers to the process of reallocating resources as new information becomes available regarding ecological changes, ecological risks and costs and benefits of interventions. Adaptive responses imply updating the scope and scale of environmental management interventions, and modes of intervention, based on critical, reflexive assessment. Patterns of socioeconomic resource allocation and institutional changes often fail to reflect up to date information regarding problem definitions and trajectories, as social systems are characterized by inertia, a degree of path dependency and, sometimes, “lock in” (David 1985). Attention to changes over time of the previous criteria – prevention orientation and spatial targeting – provides additional means of assessing temporal targeting. In an adaptively coupled system, over time, as ecological risks are better recognized, we hypothesize a more prevention-oriented posture that favors prevention oriented approaches to farming over remedial ones (H3.1). In addition, as sources of ecological risks are better recognized, we hypothesize that spatial targeting will intensify over time (H3.2).

## ***4 Methods***

### **4.1 The USDA CRIS System**

We conducted an analysis of federally funded agricultural research in the U.S., for the period 1998-2005, as documented in the U.S. Department of Agriculture (USDA) Current Research Information System (CRIS). CRIS is maintained, in part, to enhance accountability in federal spending, and it represents the nation’s most

comprehensive record of public spending on agricultural research and extension. CRIS projects reflect federal spending priorities as well as state-level demands and the interests of individual researchers. By virtue of the administrative process in selecting projects for funding, the interests of local and non-local actors are ostensibly integrated.

We depart from previous critical studies of the CRIS (Lipson 1997) in that we do not rely strictly on the dataset made publicly available on the USDA Cooperative State Research, Education and Extension Service (CSREES) web site because this data set only includes current projects and those completed in the past three to four years. To be able to assess the project portfolio over a longer time frame, we used the full CSREES electronic archive of full-text CRIS records, which extends back to 1998. At our request, USDA staff conducted a keyword search of the CRIS archive based on a list of search terms that we developed in consultation with an interdisciplinary group of researchers familiar with our research objectives (Table 1).

Table 1 Search terms structuring our query of the USDA's Current Research Information System (CRIS) 1998-2005.

Search terms		
application rate	inhibitor	Rhizobium
cover crop	Irrigation	slow release
crop rotation	Legumes	soil test
fertilizer	Management	Tillage
fixation	nutrient management	use efficiency
Gulf of Mexico	nutrient use efficiency	variable rate application
hypoxia	precision agriculture	water quality

Our query generated a set of 9759 records; after checking for duplicates a total of 4741 records remained; each record representing a “project year”, our basic unit of analysis. A research project that was funded for three years, for example from 1998 to 2000, is associated with three discrete project year records. Each “project year” record contains the project title, names and institutional affiliations of investigators, location of research, amount of the award for that year in U.S. dollars (USD) and a project description. The data are available from the corresponding author.

On the basis of project titles and, where necessary, a complete reading of the project descriptions, we assessed the relevance of each record. Projects were retained in our dataset if they met the following selection criteria: i) the study addressed nitrogen management, reduction, or alternatives to conventional nitrogen management and ii) the study dealt with practices in row crop or vegetable systems, including practices to improve nitrogen retention off-field, such as artificial wetlands, buffers strips and bio-filters. Non-relevant records were eliminated. We coded each relevant record to signify the particular nitrogen management

practice or technique under investigation within the project. Our list of practices was derived from our search terms *ex ante*, and we expanded and culled the list as we worked through the project records. As expected, many projects focused on more than one agronomic or environmental management practice. In these cases, we assigned records the code that reflects the most prevention-oriented practice under investigation (see below for a typology). This procedural decision makes it harder to reject our hypotheses, and thus, if it introduces a bias, that bias is toward a finding of adaptive coupling.

In order to assess if and how environmental change and documented recognition of the fundamental role of agriculture in altering nitrogen fluxes are associated with changes in patterns of investment in agricultural research and development we constructed a typology of technical responses to nitrogen pollution. The concept of carbon-nitrogen (C-N) coupling discussed above in section 2.1 allows us to array a broad range of sustainable and conventional agricultural practices along a continuum that reflects relative opportunities to mitigate nitrogen pollution (Figure 2).

Farming practices that are based on ecological knowledge that supports increased C-N coupling such as the use of leguminous plants, cover cropping, crop rotation and increased use of perennials are referred to as “C-N-coupled” practices. In contrast, for the purposes of our analysis, we will refer to practices that focus on a single mechanism, nitrogen-uptake efficiency, as “C-N-uncoupled.” These include the full range of industrial agricultural cropping practices linked to the use of synthetic fertilizers including strategies geared toward applying nitrogen where and when it is needed (e.g., precision placement and slow-release formulations). A more technical discussion of this framework has been published elsewhere (Drinkwater and Snapp 2007; Gardner and Drinkwater 2009).

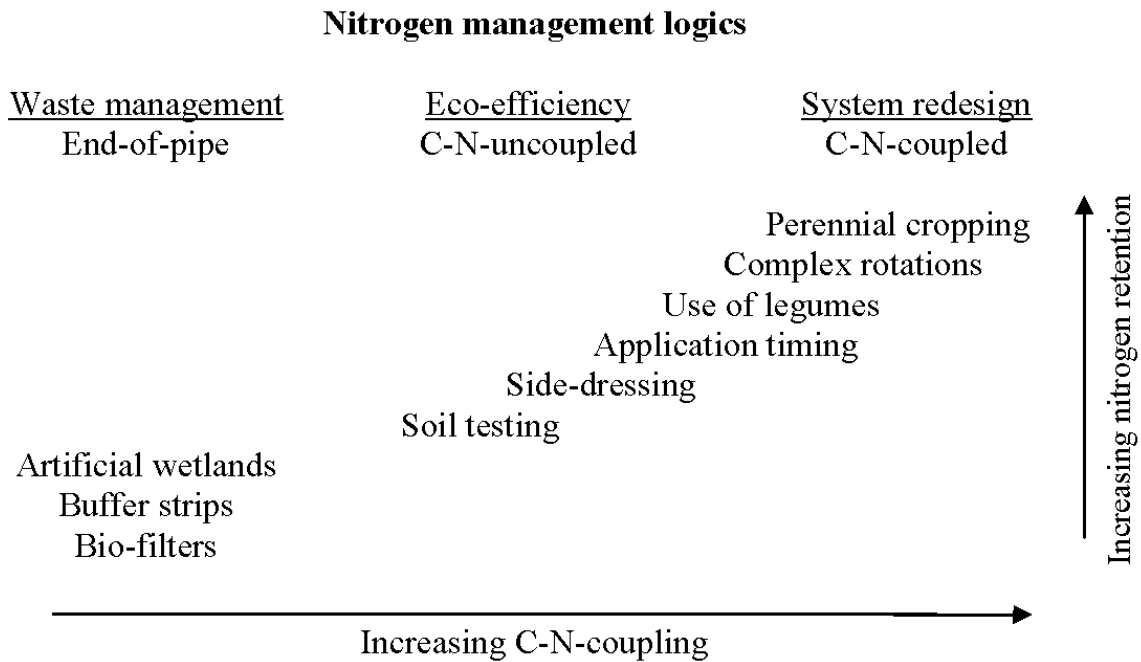


Figure 2 Typology of nitrogen (N) management practices arrayed along a continuum of carbon-nitrogen (C-N) coupling.

In addition to the set of fertility management practices in cropping systems we can array on a continuum of C-N coupling, there are a number of management practices in agriculture that are implemented outside of crop production in order to curb nitrogen pollution. We term these qualitatively different practices “end-of-pipe” practices, as they do not aim to prevent nitrogen waste from crop production, but rather aim to intercept nitrogen leaking from farm fields by various means before it reached adjacent natural ecosystems. These practices include establishment of grass buffer strips along borders of individual fields and creation of water retention basins in the lower reaches of catchments. In line with concepts from industrial ecology, we identify these end-of-pipe practices as emblematic of waste management logic, while agro-ecological approaches reflect the logic of pollution prevention and fundamental system redesign (Hawken, Lovins and Lovins 1999).



Each practice was placed into one of four categories based on the C-N continuum introduced above (Figure 2). Moving from most tightly coupled to the least tightly coupled on the continuum, the categories are *i) C-N-coupled*; practices employing agroecological approaches to farming with high effects on C-N coupling, *ii) C-N-ambiguous*; practices that can either increase or decrease C-N coupling, depending on how they are deployed, such as tillage, irrigation and manure application *iii) C-N-uncoupled*; practices aimed at fertilizer delivery with negative effects on C-N coupling, and *iv) end-of-pipe*; practices occurring off-field to capture excess nutrients not taken up by plants or stored in soil pools after application.

## **5 Results**

Total spending in the CRIS for the period 1998 to 2005 – for all research domains – amounted to 7.5 billion dollars, which supported 102,124 project years (PYs) of research, education and extension. Our targeted query identified 4741 PYs as potentially relevant to nitrogen management. After screening for relevance, we eliminated 1628 of these PYs. The resulting 3113 PYs represented 555 million dollars in spending for the continental US. Within the MRB, we identified 2143 relevant PYs and 384 million dollars, representing 5.1 percent of the total funding and 2.3 percent of the total PYs. Table 2 details the investments over the span of our study in terms of dollars and PYs and breaks out these totals into geographic units relevant for our analysis; the MRB, and within the MRB, the Corn Belt and the Gulf Coast (Table 2). Table 3 presents an overview of the N-relevant research supported in the MRB broken out by specific practices and the categories we use to structure our analysis.

Table 2 Descriptive statistics of nitrogen management research funded by the U.S. Department of Agriculture from 1998 to 2005 by USD in millions and project years (PYs).

	<b>Project Years (PY)</b>	<b>%</b>	<b>USD (millions)</b>	<b>%</b>
<b>All projects included in CRIS</b>	102,124	100.0	7,500	100.0
<b>Retrieved by keyword search</b>	4,741	4.6	948	12.6
<b>Relevant to our study, total US</b>	3,113	3.0	555	7.4
<b>MRB (31 States)</b>	2,143	2.1	384	5.1
<b>Corn Belt States (IA, IL, IN)</b>	246	0.2	23	0.3
<b>Gulf States (AL, LA, MS)</b>	176	0.2	43	0.6

Table 3 Distribution of investments in research and development across nitrogen management categories in the Mississippi River Basin (MRB) from 1998 to 2005.

Category	Practice	Investments in USD (millions)		PY	
		number	%	number	%
End-of-pipe	Buffer strips	13.6	4	66	3
	Wetlands	4.8	1	36	2
	Drainage/bio-filters	3.0	1	24	1
	<b>SUBTOTAL</b>	<b>21.4</b>	<b>6</b>	<b>126</b>	<b>6</b>
C-N-uncoupled	Soil test	13.2	3	179	8
	Plant uptake efficiency	19.5	5	156	7
	Spatial variability/timing	33.0	9	145	7
	Timing	6.6	2	140	7
	Spatial variability	14.6	4	121	6
	Nitrogen crediting	1.2	0	36	2
	Slow-release fertilizers	2.0	1	26	1
	Side-dressing	0.2	0	6	0
	<b>SUBTOTAL</b>	<b>90.2</b>	<b>24</b>	<b>809</b>	<b>38</b>
C-N-ambiguous	Manure	51.2	13	388	18
	Irrigation	25.5	7	120	6
	Tillage	23.9	6	102	5
	Manure/irrigation/tillage	40.9	11	155	7
	<b>SUBTOTAL</b>	<b>141.5</b>	<b>37</b>	<b>765</b>	<b>36</b>
C-N-coupled	Cover crops	50.1	13	187	9
	Complex rotations	62.8	16	150	7
	Use of legume	13.0	3	83	4
	Perennialization	4.7	1	23	1
	<b>SUBTOTAL</b>	<b>130.7</b>	<b>34</b>	<b>443</b>	<b>21</b>
<b>Total</b>		<b>383.7</b>	<b>100</b>	<b>2143</b>	<b>101</b>

## **5.1 Prevention orientation**

Prevention orientation of the portfolio is indicated by the relative investments in the research and development categories we have defined and, most directly, by the extent to which C-N-coupled approaches are privileged. Spending is higher in the C-N-coupled category than in the C-N-uncoupled and end-of-pipe categories (Figure 3). While high investments in C-N-coupled practices are indicative of a prevention orientation, high investments in C-N-ambiguous practices present a less clear picture.

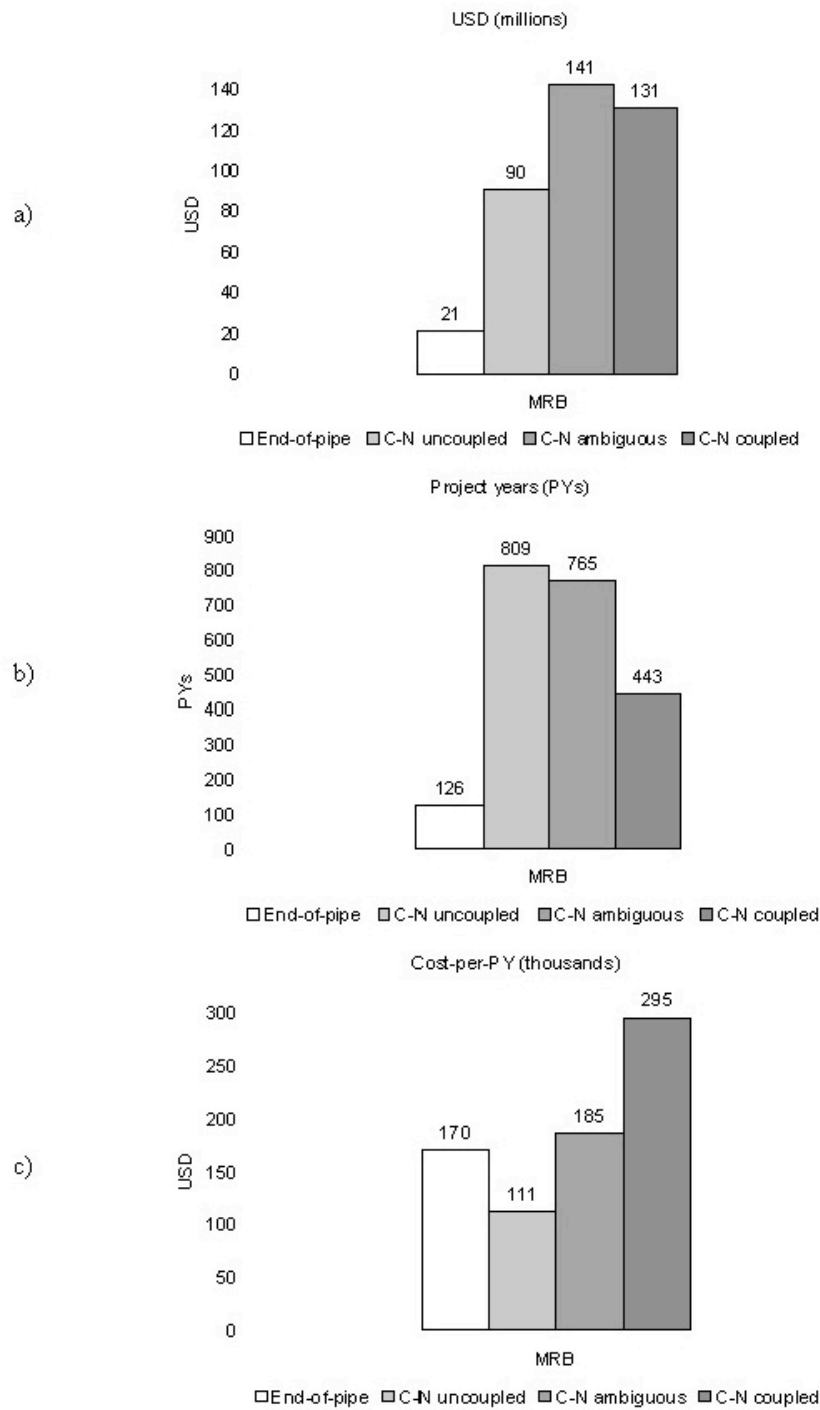


Figure 3 Distribution of investments in research and development across nitrogen management categories in the Mississippi River Basin (MRB) from 1998 to 2005 in USDA (millions), project years (PYs), and cost-per-PY (thousand) (N=2143). Please, note that not all numbers add up to totals due to rounding.

## 5.2 Spatial targeting

### 5.2.1 Spatial targeting of agricultural research spending

Spatial targeting is assessed through consideration of the extent to which resources are allocated to the most critical geographical areas: in our case, the MRB and, specifically, the Corn Belt. The Corn Belt accounted for 23 million dollars in expenditures and 246 PYs. In comparison, the Gulf States accounted for 43 million dollars in spending and 176 PYs. As shown in Table 2, the MRB accounts for most of the nitrogen research expenditures in the national portfolio (5.1 percent out of a total of 7.4 percent, or 69 percent) suggesting some degree of targeting; however, the Corn Belt accounts for only 23 million dollars of the 384 million dollars directed to the MRB for N management research and extension. This amounts to **only 6 percent** of the total MRB spending, a remarkably low proportion given what is known about the geography of the hypoxia problem.

### 5.2.1 Spatial targeting of prevention orientation

In examining resource allocation across nitrogen management categories, we observe no evidence of a greater prevention orientation in the Corn Belt relative to the Gulf States. In the portfolio of projects funded in the Corn Belt, the C-N-coupled category received the lowest investments in dollars and C-N-uncoupled practices received the highest investments in dollars (Figure 4a). In contrast, in the Gulf States, investments in dollars are highest in the C-N-coupled category. Analysis of PYs produces generally similar results (Figure 4b).

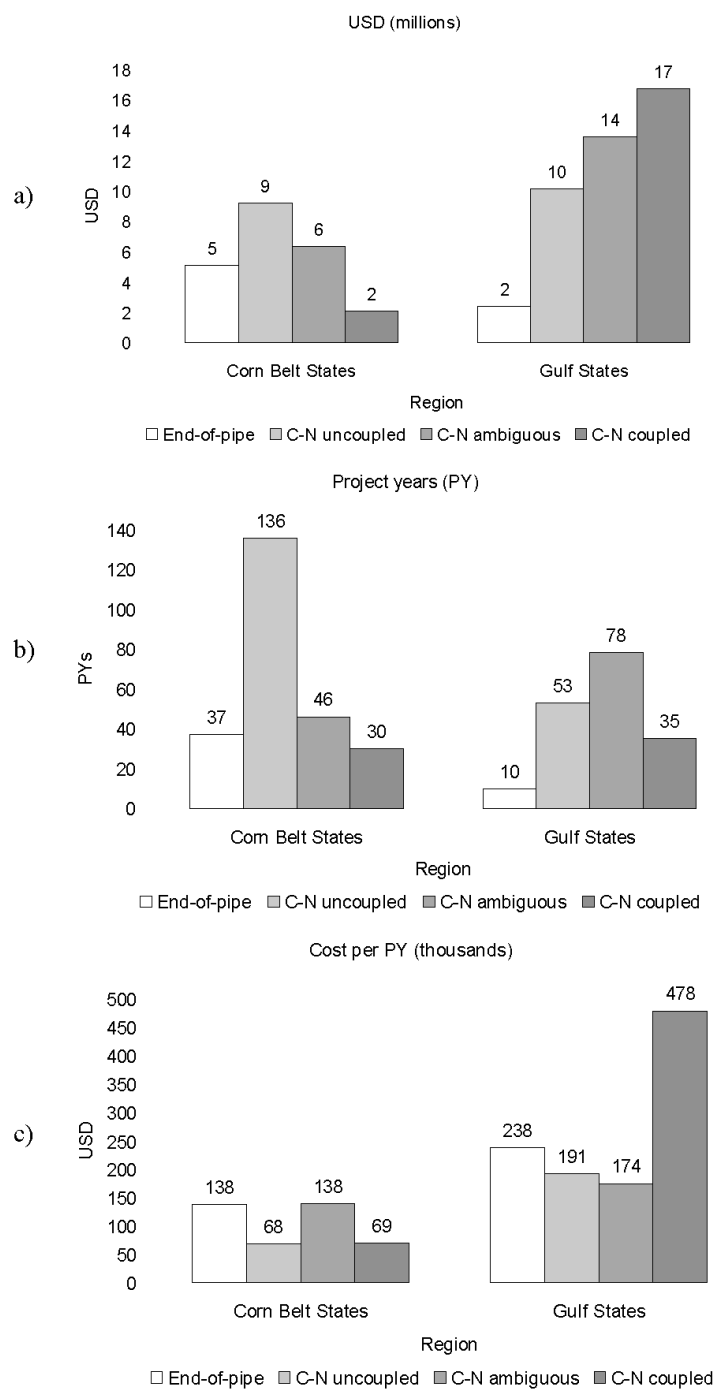


Figure 4 Investments in nitrogen (N)-relevant research categories in the Corn Belt States (N=246) and Gulf States (176) from 1998 to 2005. The bar charts show project years (PYs), spending in USD (millions), and cost-per-practice category (USD/PY) in thousands.

### 5.3 Temporal targeting

#### 5.3.1 Temporal targeting of agricultural research spending

To assess temporal targeting we analyzed changes in spending over time for the MRB, the Gulf States and the Corn Belt States.

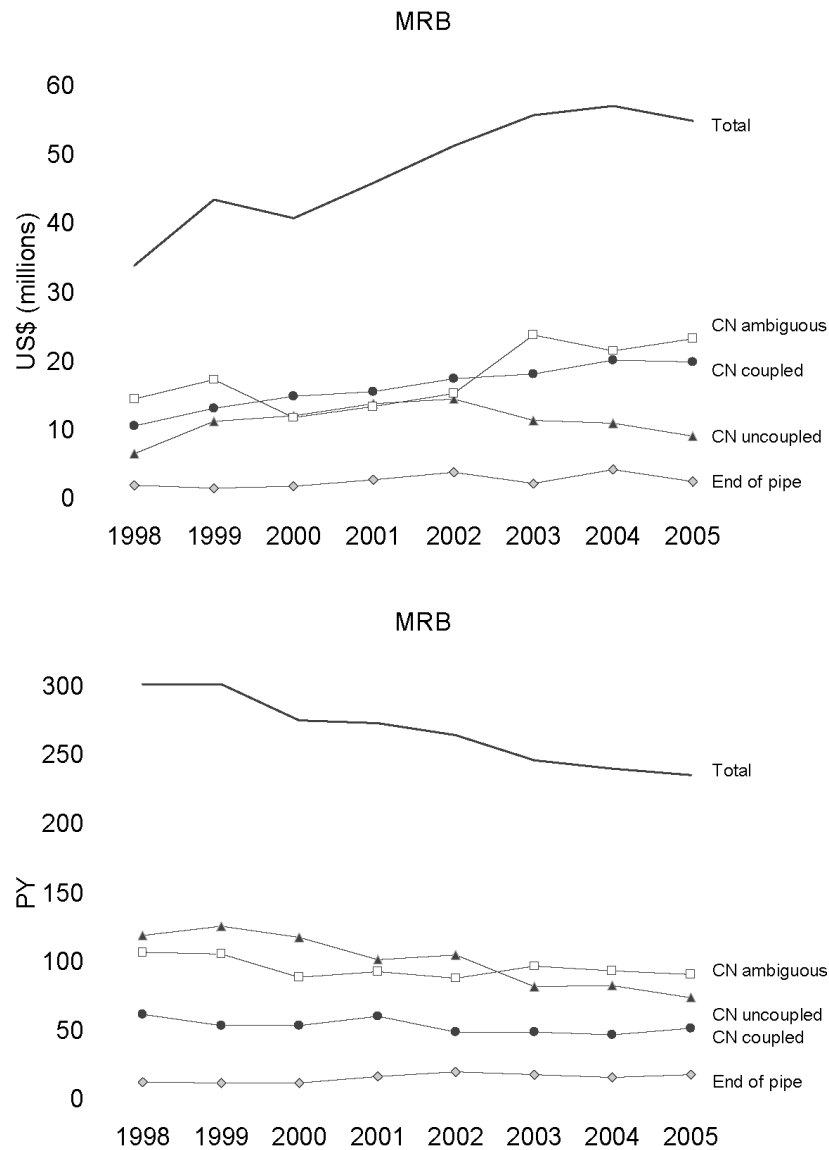


Figure 5 Time trends of investments in nitrogen (N)-relevant research categories in the Mississippi River Basin (MRB) (N=2143) from 1998 to 2005 in USD (millions).



At the level of the entire MRB, investments devoted to nitrogen management increase over time when measured in terms of dollars and decrease over time when measured in PYs (Figure 5). However, funding directed to the Corn Belt dropped by 60 percent in the period 1998-2005 (Figure 6).

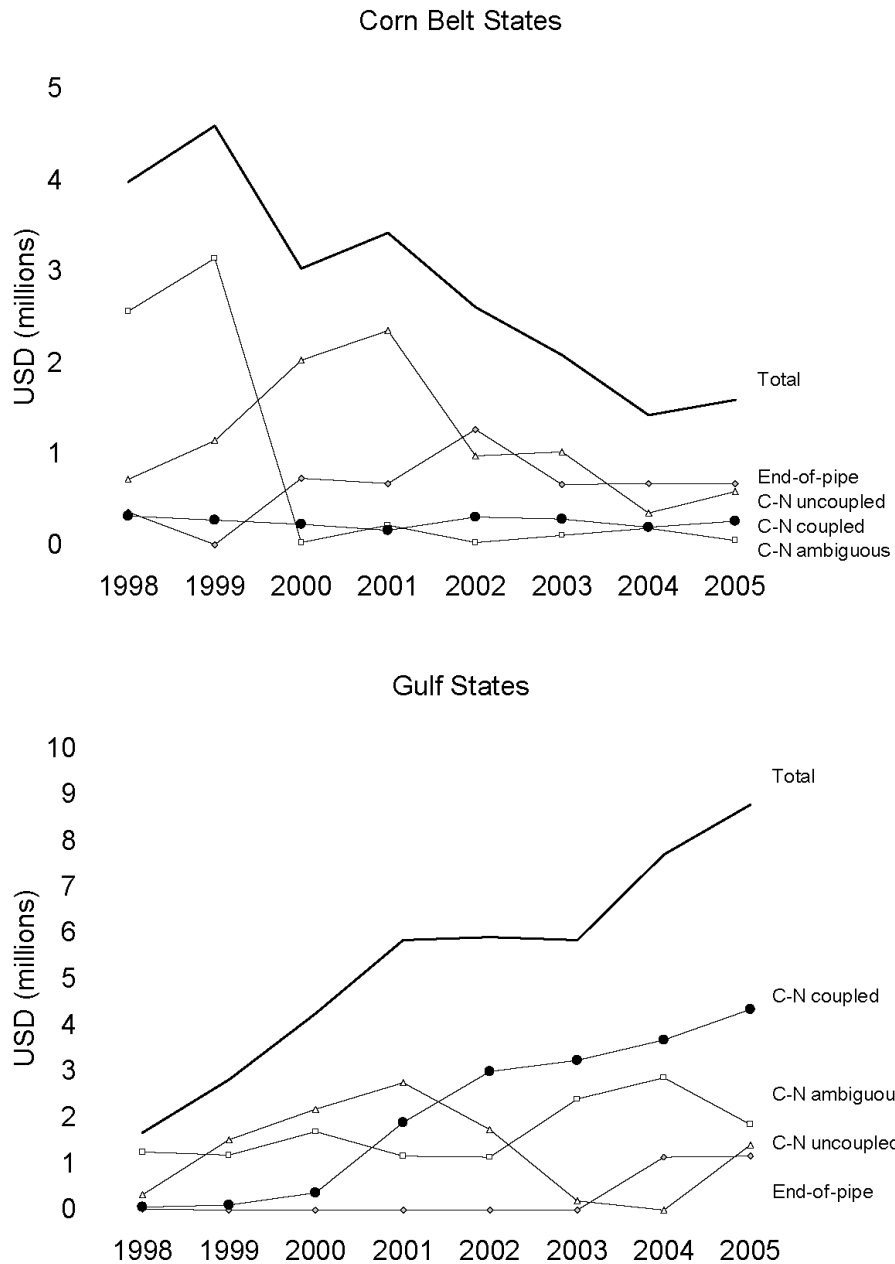


Figure 6 Time trends in investments in nitrogen (N)-relevant research categories in the Corn Belt States (N=246) and Gulf States (176) from 1998 to 2005 in USD (millions).

### **5.3.2 Temporal changes in prevention orientation**

At the level of the MRB we see an indication of increasing prevention orientation; spending increases for the C-N-coupled and C-N-ambiguous categories (Figure 5). Spending remains stable for the end-of-pipe category and decreases for the CN uncoupled category. PYs devoted to nitrogen management research remain stable or slightly decrease for all categories over time. In examining the sub-regions within the MRB, we find that the regions did not become equally more prevention oriented (Figure 6). Prevention-oriented practices captured an increasing share of dollars and PYs in the Gulf States but not in the Corn Belt.

### **5.3.3 Temporal trends in spatial targeting**

PYs devoted to the Corn Belt and the Gulf States follow the overall trend of decreasing PYs, though at a higher rate in the Corn Belt than in the Gulf States (data not shown). Figure 6 illustrates that funding devoted to nitrogen-relevant research in the Corn Belt has almost continually decreased, while funding to the Gulf States has continually increased. As reported above, funding directed to the Corn Belt – the primary source of the nitrogen causing hypoxia – dropped 60 percent in the period 1998-2005 (Figure 6).

## ***6 Discussion***

### **6.1 Does the response in resource allocation exhibit adaptive coupling?**

Our results allow us to speak to the question, Is the Mississippi River Basin (MRB), as viewed through the particular interface of federally funded nitrogen management research, an adaptively coupled social-ecological system? We can also assess trajectories, answering the question, Is the system becoming increasingly adaptively coupled over time? At the level of the MRB, investments in nitrogen management practices aimed at re-coupling carbon and nitrogen cycles receive high and increasing investments, an indication of prevention orientation (H1). However, we find that none of the other criteria, spatial targeting (H2.1 & H2.2) and temporal targeting at the regional scale (H3.1 & H3.2), are met.

Public investments are not concentrated in the Corn Belt where they might affect nitrogen losses overloading the ecosystem in the Gulf of Mexico. The findings illustrate that while a notable 69 percent of the total

federal research and development investment in nitrogen management research is allocated to the MRB (Table 2), showing clear recognition of nitrogen management as a pressing concern, the Corn Belt accounts for only 6 percent of these funds, indicating extremely poor spatial targeting of investment (Figure 5). Further, in this historical period in which the problem and causes of hypoxia have been identified and policymakers have signaled their engagement, the already small portion of funding allocated to the Corn Belt decreased by 60 percent. In line with this finding, federal investments in agroecologically oriented research decreased in the Corn Belt over the period of our study. We found significant prevention orientation in the Gulf States, but stress that this positive trend does not serve to mitigate nitrogen pollution of the Gulf of Mexico. Rather, higher and increasing investments in agroecological practices in the pollution sink area may reflect a heightened awareness of impending environmental crisis in the region. In the Corn Belt, on the other hand, funding for prevention-oriented approaches decreased.

As summarized in Table 4, we find little evidence of adaptive coupling. This result is consistent whether we rely on an accounting of dollars spent or of the numbers of projects supported. Similarly, when we look at the data aggregated geographically and temporally, or when we compare across the sub-regions or time intervals covered in our dataset, we reconfirm our summary finding of little-to-no evidence of adaptive coupling. These results lead us to conclude that the MRB is a maladaptively coupled social-ecological system. In addition, the system is on a trajectory of increasingly maladaptive coupling.

Table 4 Schematic summary of research results.

	Prevention	Spatial targeting	Temporal targeting
MRB	+	-	0
Corn Belt States	-	Na	-
Gulf States	+	Na	+

Scale: + = hypothesis supported, 0 = ambiguous findings - = hypothesis not supported.

## 6.1 The findings in context

Over time, research spending on nitrogen management practices at the level of the MRB increased at the same slow rate as overall national spending reflected in the CRIS (Schimmelpennig and Heisey 2009). Patterns of spending for individual practices and practice categories, as well as for the particular geographic regions of interest, deviate widely from this overall trend. The deviations run against our expectations for an adaptively coupled system in that they are not spatially targeted. Schimmelpennig and Heisey (2009) point out a trend of decreasing state discretion in allocation of federal funds in agricultural research, a trend that may be reason for some optimism in the context of this study. At present, existing state discretion built into the public agricultural research and development funding mechanisms has not led to adaptive coupling of the MRB system in terms of nitrogen management. State-level interests are unlikely to be oriented toward mitigating environmental risks at the scale of region or nation.

There are substantial differences between the proportion of dollars and PYs devoted to specific research activities. The discrepancy may stem from differences in the cost of research directed at different kinds of questions. An extreme example is a multi-year USDA research project in the Gulf Coast that focused on economic and ecological outcomes of changes in production systems. This single project captured six times the average annual PY investment over several years and accounted for 78 percent of spending in the C-N-

coupled category within the Gulf States. Generally speaking, interdisciplinary, systems-oriented research (or agroecological research) is expensive.

## **6.2 Study limitations**

Traditionally, research and development activities conducted by scientists and extensionists are an important resource for shaping technology and farmers' practices. Having said this, we are aware that science and formal extension programs are not the only source of information accessible to farmers. We do not subscribe to the rational myth of the linear model of technical change (Allaire and Wolf 2004). Beyond publicly funded research and extension, knowledge on farming practices is produced by individual farmers, collaboratives of many varieties, farmer professional organizations, non-profit organizations, farm input suppliers, and various organs of local government (Kloppenburger 1991). While the linear model of diffusion has been refuted in the innovation literature for decades (Rosenberg 1982), and while the public research represents approximately half of all agricultural research spending, it is still the dominant mode informing research, extension, and agricultural policy (Wolf and Zilberman 2001; Schimmelpfennig and Heisey 2009). Public investments are particularly important in technical domains that are linked to non-commodified inputs: the study of processes that are governed by knowledge rather than material inputs, which are harder to commodify (e.g. through patents). An example of commodification from agriculture is nitrogen management through the application of synthetic fertilizers, an input that must be purchased from external suppliers. An example for a non-commodified approach to nitrogen management is the implementation of complex crop rotations based on ecological knowledge, a skills-based approach that must be learned rather than purchased. Thus, while we recognize that an analysis of public agricultural research and development investments is not a comprehensive basis for surveying all relevant knowledge production processes, we believe it is a useful lens through which we can test our arguments.

Identifying variables linking social and biophysical subsystems or finding a variable that effectively shapes the relevant interface was a straightforward task. Many variables suit this purpose (e.g., regulations, on-farm behaviors, conflict over pollution, and mobilization of civil society organizations dedicated to conservation).

Moving from theory to empirical applications was, however, more challenging. Finding a relevant variable that is systematically recorded over time and across the relevant geographic areas proved very difficult and these criteria narrowed our options. Change in the composition of the federal research portfolio is, of course, only one of many relevant places to look for signs of adaptive response. Further, our ability to analyze this interface is limited by the short time for which complete digital records are available.

A major limitation facing studies that aim to evaluate interplay between institutional and environmental change is the availability of relevant geo-referenced and longitudinal data. This is true for both socioeconomic and biophysical data. Our effort to collect information on investments in the Land Grant Universities, Experiment Stations and Extension system are illustrative of this difficulty. While the CRIS financial files did allow us to study temporal and spatial trends in the federal portion of public resources allocated to research relevant to water quality, the state-level matches of federal funds are not disclosed publicly. These funds can account for up to six times the federal contribution. Furthermore, key ecological data that are needed for monitoring environmental change are collected on a very limited basis and in some cases are simply not being collected at all. For example, monitoring stations of the U.S. Geological Survey's National Stream Water Quality Accounting Network program for monitoring riverine nutrients of importance to coastal waters has declined from 500 in 1974 to 32 in 2004 (USCOP 2004). Another example is data detailing tile drainage on farmland. These data are no longer collected despite the overriding importance of this practice in increasing nitrate leaching losses from agricultural fields (USNRCS 2010).

## ***7 Conclusion***

### **7.1 The persistence of maladaptive coupling**

In summary we conclude that the Mississippi River Basin, as viewed through the particular interface of federal nitrogen management research funding, is a maladaptively-coupled social-ecological system and is continuing on this trajectory of increasing maladaptive coupling. Geographic disaggregation of the data shows a dramatic lack of adaptive coupling with limited and decreasing investments targeted toward the source of pollution. We therefore stress the importance of geographically referenced data, attention to relevant scales of

analysis and their interactions, and the need to develop case-specific analytic concepts in order to assess adaptive coupling of social-ecological systems.

The current disconnect between recognition of large scale environmental effects of nitrogen pollution and institutional arrangements is typical of many current environmental problems, and mechanisms linking natural and social sub-systems in such cases are the area of lively debate in the ecological and social sciences alike. We selected a continental scale environmental problem in order to address problems of a) long-distance and long-term pollution and b) scaling and coordination across distance, time, and levels of social organization. In addition, we focus on one of the defining features of industrialized societies, mobilization of nitrogen and, specifically, the de-coupling of carbon and nitrogen cycles in agriculture. Thus, our case speaks through its scale and content to a general type of environmental management problem of global relevance.

In this light, our research findings can be understood through a general reference to the potentially complementary roles public research funding plays in legitimizing state authority on the one hand, and achieving substantive environmental improvements, on the other (Frickel and Davidson 2004). Investing in environmental management and pollution can support a state's claim to be actively engaged in addressing risks to citizens and ecosystems, in our case by funding an array of research projects. Such investment may or may not represent a substantive response to those material risks, in our case study by reducing the hypoxic zone in the Gulf of Mexico. In an adaptively coupled system, expanding legitimacy of responses to environmental problems would derive from and support interventions that have the potential to mitigate relevant risks. While at first glance public spending on nitrogen-relevant agricultural research, as a reasonably large, sustained multifaceted portfolio of research and development, would seem to constitute a substantive response to the problem of Gulf hypoxia – disaggregating the data by technical approach, geography and time highlights the weakness of the adaptive response. The paradigm and practice of nitrogen management in the Corn Belt is not likely to be challenged in the near future based on the current pattern of investment. We have demonstrated that spending in the pollution source area is small, getting smaller, and focused on a kind of knowledge production with little prospect for addressing the mechanisms of environmental degradation at

work. In this sense, our findings suggest that public investments in agricultural research and development respond to environmental change in a symbolic rather than a substantive manner.

The conservative nature of public agricultural research spending points to a tendency to exploit the existing agricultural system that serves to produce desirable outputs in the form of food, fuel, economic returns and a form of sociopolitical stability. Consideration of the trade-offs between *exploitation* and *exploration* in economic domains (March 1991) suggests that U.S. federal agricultural research and development is currently forgoing opportunities to develop and scale up understanding and implementation of alternative modes of production. Failure to invest in exploration reduces prospects for overcoming current contradictions between production and conservation through integration of environmental benefits into crop production, as well as by decreasing the dependence of farming on extra-local, fossil-fuel-derived inputs. Such an exploration of alternatives, in addition to the exploitation of existing knowledge in current farming practice, policy, and research, would serve to increase adaptive coupling of the social-ecological system in the Mississippi River Basin.

Our analysis is premised on a rather stylized model of the way research priorities are set and research proposals are vetted. Within this model, the state is presented as monolithic, and scientific framing of the problem of hypoxia is presented as unambiguous. Neither of these are the case. For example, the engagement of the problem of hypoxia by the U.S. Environmental Protection Agency has not been matched by USDA, which remained notably silent about the causal links between agricultural nutrient management and hypoxia until 2009 (see USNRCS 2009). However, as is often the case applied to environment, the science underlying risk assessment is challenged, and the response of the state to calls for reform are uneven across and within agencies. Individual researchers shape research agendas beyond and sometimes in contradiction to official government positions. For example, as early as 2000 the control of nutrient over-application as a means to reduce Gulf Hypoxia is mentioned in the portfolio we study. These realities should be recognized in efforts to conceptualize and assess adaptive responses to environmental change.

## **7.2 The difficulties and merits of operationalizing notions of coupled systems**



Our effort to specify and empirically assess what constitutes adaptive social-ecological coupling in the Mississippi River Basin raises questions about the value of such an exercise and the generalizeability of the particular scheme we have introduced. We have focused on the empirical assessment of patterns of socioeconomic resource allocation in response to environmental change. While there needs to be ongoing, critical reflection on what criteria should structure such an analysis, the criteria we derived – prevention orientation, spatial targeting and temporal targeting – strike us as meaningful and sufficiently flexible to encompass a broad range of applications. Of course, the ways in which these generic criteria are operationalized in the context of particular research objectives will vary from system to system and within systems over time (Carpenter et al. 2001). Such efforts will be based on collaborations among social and natural scientists that take us “beyond natural science research in which human actions are treated as exogenous or largely ignored, and social science research that fails to consider the impact of biophysical forces” (Kotchen and Young 2007: 151). To be a resource for management and policy and to support public debate, we need to know if and how adaptive social-ecological coupling is manifested in particular settings at particular spatial and temporal scales, and how ecological and institutional environments constrain and enable adaptive coupling.

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## CHAPTER 3

### ADAPTIVE SOCIAL RESPONSE TO GULF HYPOXIA: PROXIMITY EFFECTS IN THE MISSISSIPPI RIVER BASIN FARMING SECTOR

*A future version of this chapter co-authored with Steven A. Wolf will be submitted for publication.*

#### *Abstract*

In this article, adaptiveness of social response in organizations that are subject to increased environmental accountability demands is defined by the nature of the investments they make in resources to meet those demands. Studies that take into account how local institutional and ecological contexts affect whether and how organizational resources link to organizational environmental behavior are rare. Proximity economics provides explanations for the distribution of social responses to ecological risks, such as excess nitrogen, based on the social actors' geographical and cognitive "proximity" to these risks. Variation in the distribution of response types is especially important in biophysically and institutionally heterogeneous landscapes such as the Mississippi River Basin. Based on semi-structured interviews with representatives of 35 organizations in Iowa and Louisiana, we find counter-intuitive and maladaptive resource investments in light of broader social sustainability goals. Namely, we find that goals regarding ecological improvements as stated in organizational missions and by organizational representatives do not correspond with organizational investments. We evaluate the utility of the proximity approach in recognizing opportunities for and obstacles to supporting sustainability transitions at the level of organizational fields.

#### *1 Introduction*

Adaptive social response is an important concept in sustainability studies (Becker et al. 1999; Folke et al. 2002; Armitage et al. 2008). Sustainability studies aim at sustaining and improving living conditions for human populations by analyzing and optimizing the feedbacks that occur between social and biophysical system components (Norgaard 1994). Therefore, sustainability studies often support a normative research agenda (Gladwin et al. 1995; Becker et al. 1999). Within such an agenda, we consider a social response that leads to



environmental or socioeconomic degradation as maladaptive. In contrast, social responses that prevent environmental degradation are considered adaptive behavior (Hufnagl-Eichiner et al. 2011).

Social responses at the levels of organizations, sectors and territories are shaped by multiple and layered institutional pressures: the formal and informal rules that govern social processes (Scott 1995, DiMaggio and Powell 1983; Meyer and Rowan 1977). When institutional demands change—for example, when social demand to meet environmental goals increases—organizations respond by mobilizing resources (Nelson and Winter 1982). Resources are the semi-permanent tangible and intangible assets of an organization, such as capital, staff or knowledge that can constitute both strength and a weakness of the organization (Wernerfelt 1984).

Primmer and Wolf (2009) are successful in documenting investments in resources by organizations that are subject to institutional pressures due to increased environmental accountability. Environmental accountability describes the demand on organizations to address ecological risks in order to maintain legitimacy. However, in Primmer and Wolf's statistical analysis few of the observed resources map onto organizational outputs. As a consequence, they call for inquiries that take into account how variation across local institutional and ecological contexts might affect whether and how organizational resources link to organizational environmental behavior.

A theoretical framework from proximity economics provides a tool to analyze the concept of geographical and cognitive proximity of social actors to (for example) ecological risks in light of the variation across institutional and ecological contexts (Torre and Zudineau 2009; Mollard and Torre 2004). The proximity framework therefore can potentially serve to produce explanations for the distribution of social responses to changing institutional demands in biophysically and institutionally heterogeneous landscapes. Proximity economics is concerned with multiple dimensions of proximity and its effects on social and economic behavior. Examples of these dimensions are geographic proximity, indicating the distance between social units, for example firms, and cognitive proximity, indicating the overlap in mental representations between social units.

We test our specific assumptions about the nature of social response to environmental accountability demands in the case of the dead zone in the Gulf of Mexico. The dead zone, a low-oxygen or hypoxic zone in the Gulf is primarily caused by nitrogen fertilizers leaching from farm fields in the far-away upper reaches of the Mississippi River Basin (MRB) (David et al. 2010). Hypoxia in the Gulf of Mexico is but one manifestation of the doubling of reactive nitrogen in the earth's atmosphere since the invention of the Haber Bosch process (Vitousek 1997). Excess nitrogen not only poses a risk to the Gulf of Mexico, but also has been shown to be one of the major threats to future human well-being. (Rockström et al. 2009). As such, it constitutes a clear challenge to sustainability.

In order to analyze the adaptiveness of organizations' resource investments with respect to Gulf hypoxia, we derive a hierarchy of intervention logics (end-of-the-pipe, rationalization, and prevention). We will use this hierarchy twofold: First to structure the analysis of cognitive proximity effects on resource investments, and secondly to rank organizational program types in response to institutional pressures. We propose a set of organizational resources, from educated staff to financial investments, which allow quantitative assessment of the support different program types receive in organizations. Based on semi-structured interviews with representatives of 35 organizations in Iowa and Louisiana, we analyze the scale and distribution of organizational resources and programs in relation to geographic and cognitive proximity in the MRB. In conclusion, we discuss the role of proximity effects in shaping organizational adaptation to environmental accountability demands. Based on the insights we derive, we evaluate the utility of the proximity approach in recognizing opportunities for and obstacles to supporting sustainability transitions at the level of organizations, sectors and territories.

## ***2 Conceptualizing adaptive social response***

### *2.1 The organizational field*

While the farming practices to curb nitrogen leaching are implemented at the field and farm levels, farmers do not operate in a vacuum. Much of a farmer's activity is based on know-how neither produced nor producible by an individual, or even by a single group or organization. Rather, knowledge exists distributed in the

organizational field (Savage 1994; Wolf 2008; Moore 2008). An organizational field is defined as “those organizations that, in aggregate, constitute a recognized area of institutional life: key suppliers, resource and product consumers, regulatory agencies and other organizations that produce similar services or products” (DiMaggio and Powell 1983: 148). Because farmers’ technical practices are embedded in the organizational field, farmers are pressured to function within this organizational field despite potentially detrimental impacts on farm viability and land health (Bell 2004). More positively, the organizational field structures opportunities for learning and change through which conservation can occur. Therefore, the study of social adaptation must address the level of the organizational field.

## *2.2 Resource investments in response to institutional pressures*

A theory of adaptive social response requires specification of the mechanisms that link institutional pressures and organizational outputs, and the variables that mediate these linkages. Institutional pressures are the formal and informal norms and rules that set the boundaries for acceptable social behavior (Meyer and Rowan 1977; North 1991; Scott 1995). Organizations, in an effort to meet changing institutional demands and bolster competitiveness, respond by investing in organizational resources that are not easily obtained or created by others (Nelson and Winter 1982; Barney 1991). The interplay between resources and outputs is an iterative process through which organizations and their environments co-evolve. This occurs as organizations develop or stumble upon new routines. According to coevolutionary logic, changed organizations lead to changes in the institutional as well as the ecological environment. In turn, an organization’s failure to adapt, by means of differentiation, to changing social and ecological changes increases its risk of falling prey to selection pressures exerted by these demands (Lewin and Volberda 2003; Porter 2005).

Differentiation is difficult because organizations in a field tend to become similar by orienting their behavior to that of others and by responding to shared institutional pressures (DiMaggio and Powell 1983). The benefit of such “isomorphism” is that it enhances coordination among field members and, thus, survival of the individual organization (Deephhouse 1996; Baum and Oliver 1991). Its disadvantage lies in the reduction of potential for innovation, because performing outside the institutional norms is not considered legitimate

(Zucker 1987). Engaging in non-legitimate behavior sets an organization apart from its field members, reducing effective exchange with them. Such exchange, however, is crucial for the procurement of key organizational resources (DiMaggio and Powell 1983).

Our insistence on organizational resources as critical to organizational adaptation is based on the argument that changes in institutional demands necessitate changes in internal resources in order to implement programs in organizations that can lead to ecological improvements (Wolf and Primmer 2006). Primmer and Wolf (2009) support this argument by successfully documenting investments in resources by organizations that are subject to institutional pressures relating to increased expectations for biodiversity conservation in forest management. However, they find limited statistical support for their thesis that resource investments are associated with increased rates of habitat conservation. They attribute this lack of explanatory power to two factors: 1) they do not account for local biophysical and institutional variation among the members of the organizational field they study, and 2) they account only for resources that lend themselves to objective measurement and 3) do not include measures of cultural-cognitive factors affecting resource allocation. To date, few studies consider material-technical and cultural-cognitive factors as complements in shaping organizational response to environmental accountability challenges (Hoffman 2001; Scott 2002). Those that do are able to present detailed analyses of the interplay of material-technical and cultural-cognitive factors in shaping organizational environmental adaptation (Bansal 2004; Marshall and Standifird 2005).

In our search for adaptive social response, we start with the premise that adaptive response cannot be expected to be rational, progressive, or uniform. We need to account for local biophysical and institutional heterogeneity in order to understand and analyze the adaptiveness of social response. Proximity economics provides an innovative framework to incorporate this variation as factors explaining organizational behavior. We will apply the proximity framework to analyze resource investments in an organizational field.

### ***3 Proximity effects on resource formation***

Building on insights from transaction cost economics, the proximity framework seeks to analyze the implications of friction that constrains social coordination. Proximity economics considers geographic

proximity, the co-localization of social actors, as well as cognitive proximity, which refers to shared mental maps of social actors. What unites cognitive proximity and geographic proximity is the fact that both “reduce uncertainty and solve the problem of coordination, and, thus, facilitate interactive learning and innovation” (Boschma 2005: 62).

### *3.1 Geographic proximity*

In its most common application, proximity refers to the geographic distance between organizations. A key insight derived from studying the effects of geographic proximity is that it is linked to increased local resources that support local innovation (Rodriguez-Pose and Crescenzi 2008, Sonn and Storper 2003). Recently, another application has emerged, broadening the concept to include proximity “to objects other than productive relations.” Environmental pollution is the prime example of these “other objects” (Torre and Zudineau 2009: 2). Interest in this application has grown significantly in recent years, “following the realization that environmental processes and changes have local origins and impacts” (Mollard and Torre 2004: 221). The place-based nature of environmental pollution production and impact makes it important to consider the geopolitical nature of social response. To date, most environmental policies are state-level and clear differences between states exist. In addition, national level legislation such as the Clean Water Act call for implementation at the state level. In other contexts, state boundaries as established units have exhibited distinguishable patterns of investment elsewhere (Sonn and Storper 2003) and will be used accordingly in this study.

### *3.2 Cognitive proximity*

In explaining the remediation of environmental problems, proximity to a site of pollution *impact* does not consistently translate in remediative intervention of social actors (Crenson 1971; Schnaiberg 1980; Gould 1993). In fact, we argue that in cases of long-distance pollution problems such as excess nitrogen in the Gulf of Mexico, even when a social response occurs at a site of pollution impact, this response might be neither necessary nor adaptive with respect to remediation. Rather, proximity to the *origin* of pollution is a more important factor determining adaptiveness of the social response if the aim is pollution prevention. Only if

those producing pollution respond adaptively, e.g. through the formation of critical resources and programs, can we expect sustainability at the level of the MRB. It is in this sense of proximity to pollution *origin* and pollution *impact* that the proximity framework provides a tool to analyze the variation in local biophysical conditions when studying adaptiveness of social response.

Factors other than geographic proximity to environmental pollution have long been shown to drive social response (Crenson 1971; Schnaiberg 1980; Gould 1993). Proximity economics has therefore expanded the notion of proximity to include cultural-cognitive definitions in addition to geographical ones. Specifically, cognitive proximity refers to the shared mental maps of social units (Boschma 2005; Torre and Rallet 2005). Organizations that share similar references, metaphors and knowledge generally find it easier and more efficient to collaborate due to reduced uncertainty, and thus learning is facilitated (Rodriguez-Pose and Crescenzi 2008; Mangematin 2008). In contrast, differing systems of understanding lead to fragmented learning and poor adaptation (Robbins 2008). For example an organization might be considered proximate to certain ways of thinking about potential intervention strategies. It might share these ways of thinking with like organizations and might be cut off from others who think and reason differently (Boschma 2005).

In this sense, cognitive proximity can be seen as an internal resource that facilitates coordination among organizations. In addition, the shared knowledge claims that constitute cognitive proximity unite organizations in epistemological groups of apprehending the world, potentially regardless of geographical location. In the sense that cognitive proximity connects and embeds organizations in discourses and behaviors, it might serve as an important mediator of resource formation. In our case, cognitive proximity provides shared representations about what Gulf hypoxia means and what interventions are valid. We aim to analyze the effect of these representations on resource allocation.

#### ***4 Agricultural practice and nitrogen pollution***

##### ***4.1 Hypoxia in the Gulf of Mexico***

The Mississippi River drains an expansive area of former prairie ecosystems, which has been transformed into one of the major grain baskets of the world. The region delivers water to the Gulf of Mexico where, every summer for the past several decades, an area of decreased oxygen (a hypoxic zone) has developed. In the Gulf, hypoxia has altered marine ecosystem structure and functioning (NSTC 2000) to a point where only “limited recovery following abatement of oxygen stress is possible.” (Rabalais et al. 2001: 327). The overwhelming scientific evidence points to disproportionately small geographic areas with intense farming systems in the upper reaches of the Mississippi River Basin as the main source of the pollutants, primarily nitrogen, causing hypoxia (EWG 2006; USEPA 2008; David et al. 2010). In the Upper Mississippi River Basin, hydrologically manipulated landscapes contain drainage pipes, so-called “tile lines,” which intercept the nitrogen-rich water as it leaches through the soil profile, facilitating rapid movement of the water and the nitrogen from fields to waterways. Reducing nitrogen loss from the sub-basins of the upper Midwest is therefore critical to reducing nitrogen loading in the Gulf of Mexico (Diaz and Rosenberg 2008).

#### *4.2 A typology of practices to reduce nitrogen loading*

We classify practices aimed at reducing nitrogen loading from farming as 1) end-of-the-pipe, 2) rationalization, and 3) prevention-oriented.

1) End-of-the-pipe strategies intercept nitrogen before it reaches a waterway through the establishment of grassy and woody buffer strips or engineered filtering trenches along field borders, and the creation of water retention basins in the lower reaches of catchments.

2) Rationalization aims at increasing efficiency in nitrogen fertilizer management: how, when, and where to apply these highly mobile forms of nitrogen in order to mitigate losses to the environment. In terms of effectiveness, Randall et al (1997) find that conventional annual crops cannot consistently prevent reactive nitrogen from leaching out of the field at safe drinking water levels below 10mg of nitrate per liter.<sup>1</sup>

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<sup>1</sup> 10mg of nitrate per liter of water is a guiding threshold. Nitrate levels at edge of field don’t necessarily speak to nitrate levels in groundwater. In addition, water treatment can remove nitrate effectively from water before it reaches the consumer. High nitrate levels at edge of field, however, do speak to the loss/waste of costly to produce resources that create further costs down stream, e.g. in the form of health problems or treatment costs.

3) Prevention strategies rely on joint cycling of carbon and nitrogen through photosynthesis, decomposition and transformations carried out by microorganisms. Management practices based on this prevention logic include reducing the length of periods without ground cover (e.g., planting winter cover crops), returning crop residues to the soil, increasing reliance on biological nitrogen fixation, and increasing perennial crops (e.g., forage legumes and grasses, woody species, and perennial grains and vegetables) (Drinkwater and Snapp 2007). The effectiveness of these practices is well documented from the point of view of pollution prevention and agricultural productivity (Clark et al., 1998; Drinkwater et al. 1998; Gardner and Drinkwater 2009). In addition to addressing the ecological dysfunction of industrial farming systems, studies exist that indicate that social and economic benefits also stem from the introduction of prevention-oriented practices into the region: Jordan et al (2007: 1570) summarize that the “benefits included social capital formation, greater farm profitability, and avoided costs associated with specific environmental damages.”

In the coupled systems literature, Hufnagl-Eichiner et al. (2011) discuss in detail the agro-ecological foundations of the introduced typology. Here we apply it to distinguish between behavior of actors in an organizational field.

## ***5 Research Questions***

We compare the responses of organizations through an empirical assessment of their resource investments in programs directed toward hypoxia. The comparison is structured based on the presented hierarchy of responses, which allows us to assess specifically the extent to which organizations with varying levels of geographical and cognitive proximity are investing in preventative approaches. We aim to answer the overarching question of whether resource investments in organizations in the MRB farming sector suggest an adaptive social response to Gulf hypoxia. Under an adaptive response, increasing proximity to the geographic origin of pollution would translate into increased resource investments to support prevention-oriented programs. In terms of cognitive proximity, those subscribing to preventative intervention logic would be expected to invest most heavily in prevention-oriented programs. Comparing how proximity shapes



organizational resource investments in an empirical case serves to identify opportunities for and constraints to sustainability in the MRB farming sector. A set of specific questions guides our inquiry:

1. What characterizes the distribution of investments in the organization fields? What specific resources go to support prevention-oriented programs?
2. Do distinct patterns of resource investments emerge when proximity measures are considered?
  - 2.1 Is variation in geographic proximity to the pollution source associated with variation in resource investments, with special attention to support for prevention-oriented program types?
  - 2.2 Is variation in cognitive proximity associated with variation in resource investments, with special attention to support for prevention-oriented program types?

## ***6 Methodology***

### *6.1 A framework for recording organizational resource formation*

In order to systematically take into account a variety of resources relevant for adaptive social response we rely on a framework developed by Wolf and Primmer (2006). Conceptually, the formation of organizational resources underlies the organizational outputs on which environmental improvements rest (Wolf and Primmer 2006). To derive the specific resources to measure in the MRB, we rely on the established notion of capitals (Emery and Flora 2006). According to these authors, key “capitals” supporting organizational performance are 1) financial, 2) human and 3) social.

- 1) Financial capital refers to the budget investments that give status, importance, and real-world impact to programs within organizations (Giddens in Ehrenfeld 2002). Budget investments in turn fund human capital.
- 2) This second resource of interest—educated, experienced and skilled labor—is necessary to execute the tasks and develop the strategies that make organizations competitive (Lado and Wilson 1994). The staff in organizations holds the knowledge upon which the organization can draw; this knowledge is acquired through

formal education, specialized training, and experience (Scott 2002, Primmer and Wolf 2009). An organization's staff is also in contact with people in other organizations.

3) These links to others constitute the third form of capital: social capital. Network linkages to other organizations support the creation of and access to further resources through the exchange of social, professional, and information (Just et al. 2006).

### *6.2 Selection of study sites*

For a state in close geographic proximity to pollution origin we chose Iowa. For a state in close geographic proximity to pollution impact we chose Louisiana. Iowa covers a land area of 145,743 square kilometers with a population of 3 million. Louisiana covers a land area of 51,885 square kilometers with a population of 4 million. Louisiana produces a third of the nation's oil and gas and 2 percent of its seafood. The states are archetypes in that Louisiana is where the Mississippi River flows into the Gulf of Mexico as well as where the hypoxic zone is located, and Iowa is the nation's largest corn producer (Figure 7).

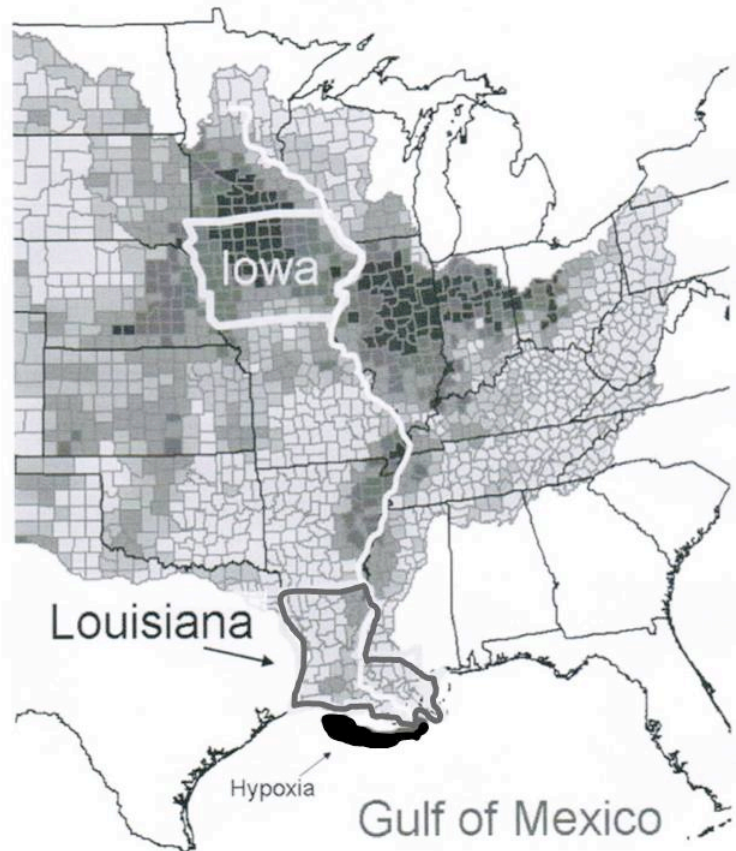


Figure 7. Map of research area. The shading indicates a county nutrient leakiness index for the Mississippi River watershed; the darker the shading, the greater the loss of nutrients (David et al. 2010). The light line indicates the flow of the Mississippi River.

### 6.3 Organization selection, interview process and analysis

In both states we selected a first set of respondents from news releases and expert opinions and continued the search for organizations *in situ* until redundancy was achieved. In the summer of 2007, the lead researcher conducted 45 semi-structured interviews with representatives of 37 organizations. Representatives generally included executive leaders and program staff.

The interview guide contained questions addressing 1) nitrogen-relevant resource investments, spending, staff, and network linkages, 2) programs, and 3) problem definitions and solution assessments. All interviews were transcribed and coded in Atlas.ti. The resource investments were assessed based on the typology

introduced above, first for all organizations interviewed, then disaggregated by geographic and cognitive proximity.

## **7 Results**

### *7.1 Resource investments in response to Gulf hypoxia in the MRB*

Of the 37 interviewed organizations, only four had implemented prevention-oriented programs in 2007. Twenty-four had rationalization programs and seven organizations had end-of-the-pipe programs. Two organizations had basic research programs that could not be categorized within the introduced hierarchy; their resource investments were excluded in the following results. The 35 organizations analyzed spent between 0 and 46 million dollars each, and a total of 100 million dollars on nitrogen-relevant programming in the year 2007. This sum represented 20 percent of the total annual budget of all of these organizations combined. The interviewed organizations employed between 0.1 and 24 full-time equivalents (FTE), totaling 115 FTE in nitrogen-relevant programming, which represented three percent of the total staff of all these organizations combined. The 35 organizations had between 2 and 29 external links each pertinent to nitrogen management issues. Together, they maintained a total of 392 financial, informational, and collaborative links either to each other or to 183 peripheral organizations—that is, organizations that had not been named more than once as key players by the interviewed organizations.

The resources invested supported predominately rationalization programs (Figure 8). Prevention-oriented programs had the support of a total of 28 FTE and 63 network linkages in four organizations. In contrast, rationalization programs had the support of 62 FTE in 24 organizations which maintained a total of 247 network linkages. Funds to prevention-oriented programs totaled 3 million dollars, and funds to rationalization-oriented programs totaled 80 million dollars. End-of-the-pipe programs received 17 million dollars, 25 FTEs and 81 network linkages. (Figure 8).

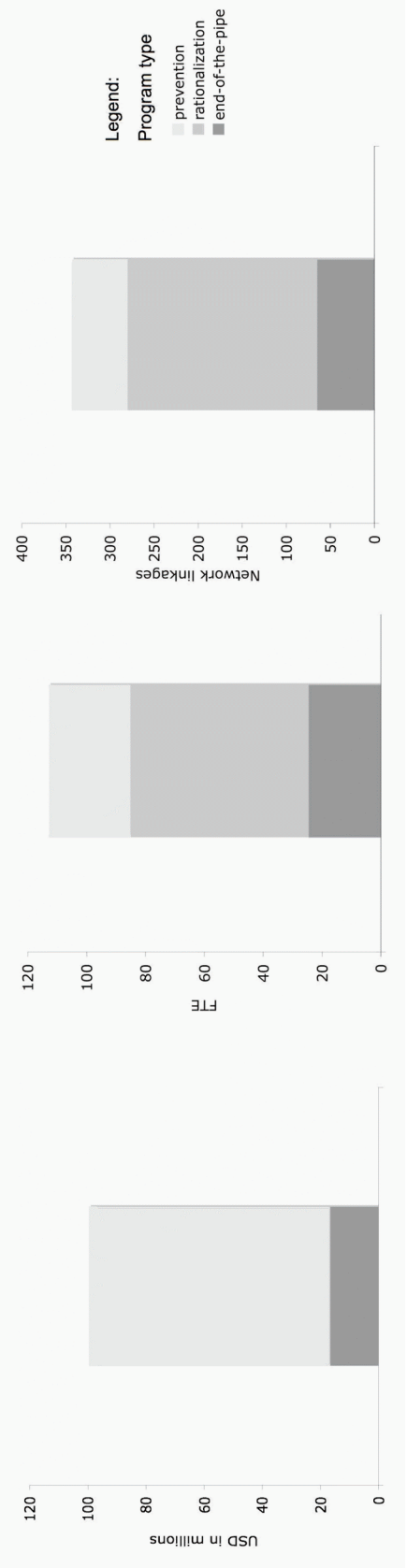


Figure 8 Combined material resources (USD, FTE, Network linkages) by allocation to program category, totaled among all interviewed organizations

## *7.2 Distinct proximity effects on resources and programs*

### *7.2.1 Geographic proximity effects on resources and programs*

Resource investments vary in important ways among the organizations interviewed in Louisiana and Iowa (Figure 9). The 15 organizations analyzed in Louisiana exhibit considerably lower levels of all resources than the 20 organizations interviewed in Iowa. While we interviewed only a quarter more organizations in Iowa than in Louisiana, spending in Iowa was sixteen times that of Louisiana: 96 million dollars versus 6 million dollars. However, the Iowa and Louisiana organizations interviewed spent about the same proportion of the funds available to them on nitrogen-related programming: namely, 26 percent of total funds in Iowa and 29 percent in Louisiana. The differences in nominal resources are less pronounced for staff and network linkages (Figure 9).

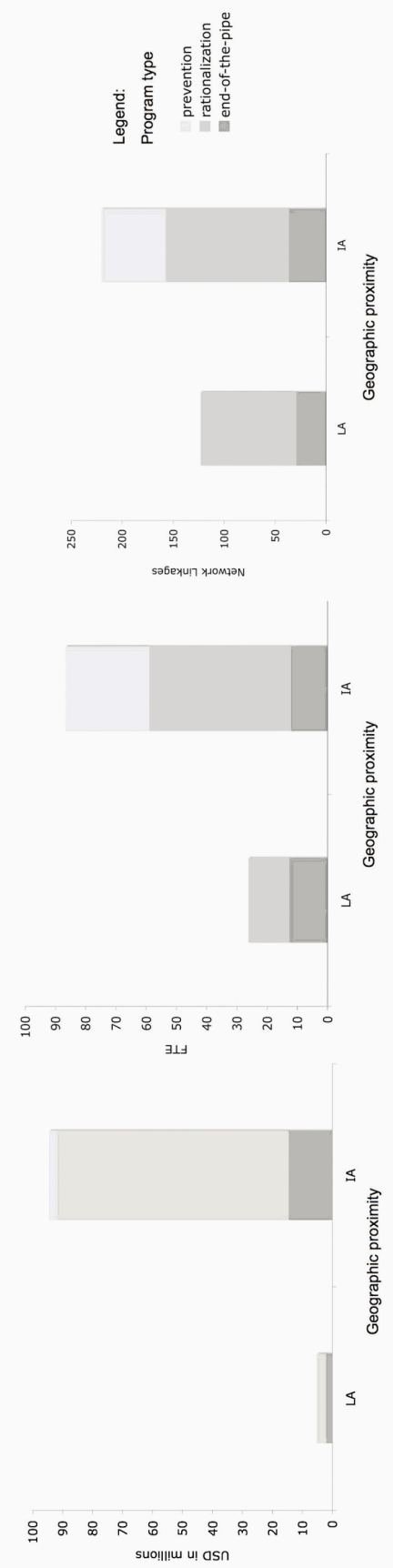


Figure 9 Resources (USD, FTE, Network linkages) by allocation to program category, disaggregated by geographic proximity to pollution production (Iowa – IA) and pollution impact (Louisiana – LA).

In Louisiana, the interviewed organizations employed 26 people in nitrogen-relevant programming, versus a total of 87 in Iowa. These numbers represented 2 percent and 4 percent, respectively, of the combined staff of the interviewed organizations in Louisiana and in Iowa. In Iowa, the majority of resources supported programs with a rationalization logic. In Louisiana, for spending and staff, equal support was given to rationalization and end-of-the-pipe program types. Only in Iowa do we find resources supporting prevention-oriented programs.

### *7.2.2 Cognitive proximity effects on resources and programs*

Of the interviewed respondents in organizations, 6 listed practices following an end-of-the-pipe logic as holding the most potential to solve nitrogen-related water quality problems, 17 listed rationalization practices, and 12 listed prevention-oriented practices. We consider the interviewed organizations cognitively proximate to the intervention logic they identify, and categorize them as organizations with an “end-of-the-pipe,” “rationalization,” or “prevention” logic. Based on these labels, we can compare how problem definitions map onto patterns of resource allocation and program types (Table 5).



Table 5 Organization types in each category of cognitive proximity

<b>Cognitive proximity</b>	<b>Number of organizations</b>	<b>Organization types</b>
Prevention-oriented	15	State level federal agencies such as National Resource and Conservation Service, Federal research agencies such as those belonging to the Agricultural Research Service, Agricultural consultants' associations, University extension branches, Farmer associations, Environmental non-profits
Rationalization	16	Farmer associations, Federal Hypoxia Task Force bodies, Farm Retail Associations, Environmental non-profits, Private farm management consultants, State level federal agencies such as National Resource and Conservation Service, State Departments of Agriculture, Natural Resources, and Environmental Quality
End-of-the-pipe	6	Farmer associations, Federal research agencies such as those belonging to the Agricultural Research Service, Water quality and environmental non-profits

There are very clear and counter-intuitive patterns of resource investments based on cognitive proximity. Eighty percent of the funds invested by the interviewed organizations went to support rationalization-oriented programs; notably, ninety-four percent of these funds was spent by organizations with a prevention logic. For money and staff, prevention-oriented organizations invest the highest levels. For network linkages, rationalization organizations have the highest investments (Figure 10).

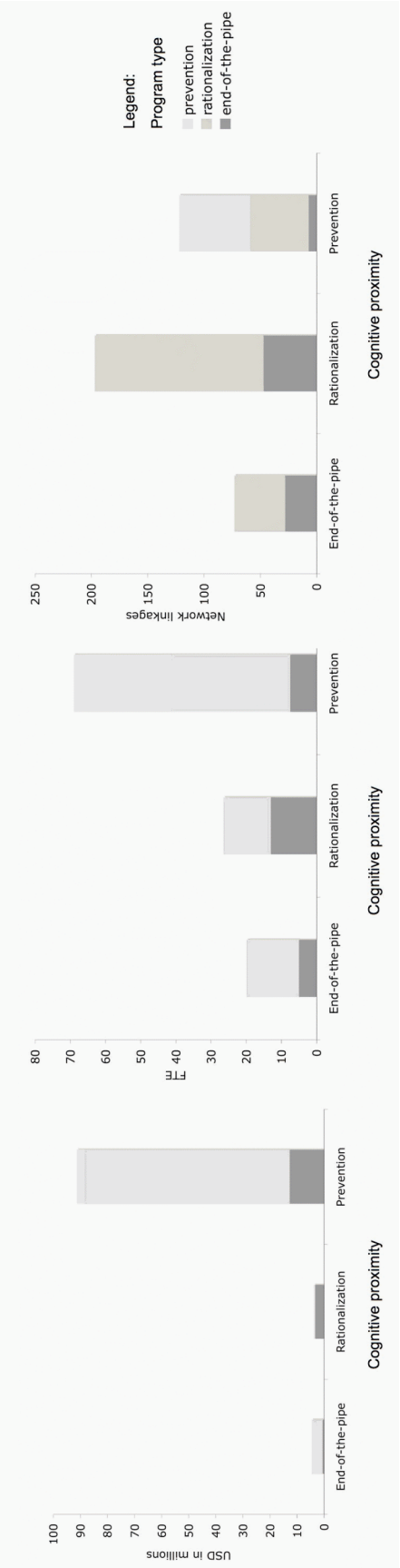


Figure 10 Material resources (USD, FTE, Network linkages) by allocation to program category, disaggregated by 1) program type and 2) intervention logic.

### 7.3 An emergent finding: From knowledge to practice – or not

Figure 11 plots cognitive proximity against the program types pursued and allows us to examine how organizations' professed positions on what constitutes appropriate interventions relate to organizational program types. Each icon in the plot represents one of the interviewed organizations. Icons indicate the location of the organizations and thus their geographic proximity to the upper reaches of the MRB, the main source of the pollution causing nitrate. The plot immediately highlights that 1) representatives of twelve organizations, those found in far right column, subscribed *in theory* to a prevention-oriented intervention logic; however, 2) only four of these 12 organizations, those found in the upper right quadrant, implemented prevention-oriented programs *in practice*. Figure 11 also shows that regardless of cognitive or geographic proximity, most organizations implemented rationalization programs.

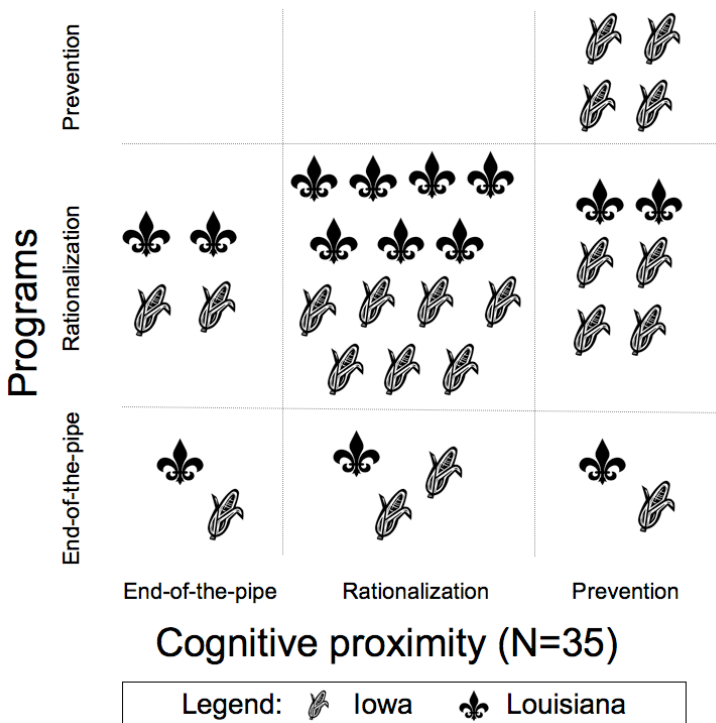


Figure 11 Direct proximity effects on organizational program orientation.

## 8 Discussion

At the onset of this analysis we argued that research on organizational investments in resources is necessary to understand and improve adaptive social response to institutional pressures for increased environmental accountability. As Wolf and Primmer (2006) argue, to date, processes of adaptation to environmental change are largely black-boxed, and few studies attend to the question of what lies between institutional pressures and adaptive organizational behavior. For us, this black box contains the actual resources that organizations invest to enhance competitiveness and legitimacy in the context of shifting accountability standards. We argued that the proximity approach would serve to generate explanations for the scale and distribution of resource investments in organizations of varying geographical proximity to Gulf hypoxia and cognitive proximity to a hierarchical set of intervention logics. We conceptualized adaptive social response as heightened resource investments in a) locations producing pollution and b) prevention-oriented programs relative to investments in rationalization or end-of-the-pipe program types. In sum, we found that adaptive resource allocation in the MRB was rare and weak, that the majority of resources went to support rationalization-oriented programs, and that this was true even for the majority of organizations that *in theory* supported prevention-oriented intervention logics.

### 8.1 The adaptiveness of social response

As expected, there was a clear response to the environmental accountability demands, as measured in resource investments: budgets, staff, and network linkages were all produced and accessed to improve the environmental performance of farming. The extent of resource investments, 100 million dollars, or 20 percent of the total budget of the interviewed organizations in 2007, demonstrates substantial interest in ecological improvements on the part of these organizations. In aggregate, however, this response appeared maladaptive: the majority of funds, staff, and network linkages invested went to support rationalization programs. To date, these strategies have not reduced the environmental degradation associated with excess nitrogen and therefore, by our initial definition, constitute a maladaptive social response.

A qualitative finding from the interviews supports the conclusion that the aggregate findings indicate a maladaptive response at a very basic level: Namely to resist change that might potentially be more prevention-oriented and disruptive. A high-profile extension program was described as “an answer to a problem,” albeit not to a pollution problem. Rather, for the respondent, a program was needed “that the EPA [Environmental Protection Agency]... will accept and work with us on” in order avoid regulation in the form of a “mandatory program.” This finding that resources have been mobilized to resist radical change rather than to effect it is consistent with studies in fields other than agriculture that consider resource mobilization and institutional change (Deephouse 1999; Sherer & Lee, 2002). Further, such a finding is fully consistent with results of studies of the political economy of technical change in agriculture (Kloppenburger 2000; Wolf and Buttel 1996; Benbrook 1996).

## *8.2 Distinct patterns of resource investments based on proximity*

Hufnagel-Eichiner et al. (2011) find that aggregate results draw an overly positive picture of adaptive social response in the case of federal research spending on farming practices. The question therefore arises whether aggregate findings in this study draw an accurate picture of the adaptiveness of social response. Therefore, disaggregating results by geographical and cognitive proximity enables us to better evaluate the adaptiveness of observed responses.

### *8.2.1 Patterns based on geographic proximity*

The results showed high nominal levels of resource investments in Iowa. In addition, in Iowa some of the observed resources went to support prevention-oriented programs. Both findings lend support to the notion that resource investments were indeed adaptive at the level of the MRB; that is, they occurred at a location that contributed disproportionately to the pollution of the Gulf of Mexico. The fact that in relative terms the investments made in Louisiana are just as high as those made in Iowa runs counter to this finding. Rather, high relative investments in Louisiana presumably indicate that regardless of the adaptive value of such a response, proximity to pollution *impact* is in some ways linked to resource allocation. Similarly, Hufnagel-

Eichiner et al. (2011) find heightened, but maladaptive, investments in geographic locations proximate to pollution impact at the level of federal agricultural research spending.

### *8.2.2 Maladaptive resource investments in prevention-oriented organizations*

Financial investments in organizations subscribing to rationalization and end-of-the-pipe logics were extremely low compared to those in prevention-oriented organizations. Organizations subscribing to a prevention-oriented intervention logic invested highest in funds and staff. Strikingly, their investments, especially financial, went largely to support rationalization-oriented programs. The following discussion will provide details and potential explanations for this observation.

## *8.3 Emerging trends*

### *8.3.1 The “rational” organizations*

Only four organizations, all sharing mission statements that stressed sustainable agriculture goals and all located in Iowa, identified with a prevention logic *and* pursued prevention-oriented program types; they are found in the upper right quadrant of Figure 11. They include a university extension agency, a government research agency, a not-for-profit producer group, and an alternative agriculture non-profit. The programs these organizations supported included political advocacy to increase support for perennial agriculture, applied research into the use of cover crops, a cover crop information exchange, and on-farm trials with cover crops and perennial crops. They varied dramatically in their resource base. One of them had the highest budget and the most staff persons allocated to nitrogen-relevant programming of all organizations interviewed, while another had only the fraction of a staff position and no dedicated nitrogen-relevant budget.

Sixteen organizations were rationalization- or end-of-the-pipe-oriented based on cognitive proximity assessment *and* implemented programs with either a rationalization or end-of-the-pipe logic. They are found in the lower left and center quadrants of the plot. Eight of them are located in Louisiana, seven in Iowa. Seven organizations are producer groups and for-profit farm managers and consultants.

### *8.3.2 The knowledge-practice gap*

Aligning with an intervention logic and pursuing associated program types accords with a general notion of what is rational. However, 15 organizations interviewed engaged in what at first sight looked like irrational behavior. That is, their representatives *in theory* supported one intervention logic, but their actual resource investments supported program types of a different kind. Most notably, eight organizations that were cognitively proximate to prevention-oriented intervention logic did not pursue prevention-oriented program types. Four of these at first sight irrational organizations were located in Louisiana, five in Iowa. They included federal and state agencies, an agricultural consultants association and a producer group, as well as three university extension branches. Seven of them were similar in that they had the dual mission goals of [pursuing] omit agricultural productivity as well as environmental conservation. Their existence serves to show that cognitive proximity to prevention logic does not automatically lead to prevention-oriented program types. They appear to show, however, that a prevention logic was a prerequisite to implementing preventative program types: not a single organization identifying with end-of-the-pipe or rationalization intervention logic pursued prevention-oriented program types.

### *8.3.3 State capture, isomorphism, and self-censorship*

Prevention-oriented practices such as perennial farming systems, crop rotations, and cover cropping hold great potential to reduce or avoid nitrogen losses from farm fields in the Upper MRB. Knowledge about these practices was common in the observed organizations and, according to the assessment of a third of the interviewees, they hold high potential to solve nitrogen-related water quality problems. Actual investments in support of these practices, however, were rare. Rather, most organizations, regardless of geographic or cognitive proximity, supported rationalization-oriented programs. Most notably, the highest amounts of funds and staff in support of rationalization-oriented programs were spent by organizations subscribing to prevention-oriented logics *in theory*. This set of organizations includes a significant number of public agencies. In stark contrast, organizations with rationalization logic invest nominally more in network linkages to support rationalization-oriented programs. This set of organizations contains almost all agricultural producer and retailer groups interviewed. In sum, investments in support of rationalization-oriented programs vary

strikingly by cognitive proximity: rationalization-oriented organizations allocate network linkages, while prevention-oriented organizations allocate financial resources. One speculative explanation might be the fact that rationalization-oriented organizations (among them many private interest groups) successfully leverage for their own goals funds from prevention-oriented organizations (among them many public organizations). Further research might be able to substantiate the hypothesis that this is achieved by means of network linkages, and is known as state capture (Hellman et al. 2000).

In addition, organizations with rationalization logic constitute the majority of the organizations that define the organizational field, thus lending legitimacy to rationalization-orientation by their sheer numbers. This legitimacy might be reflected in the high levels of organizational network linkages and might constitute an obstacle to thinking and behaving differently as theorized in the concept of isomorphism (DiMaggio and Powell 1983). Isomorphism might explain why organizations that subscribe in theory to prevention-oriented practices are not able to support these practices through actual programs because they are not considered legitimate in the organizational field. Aside from not being able to implement prevention-oriented programs, some organizations might potentially engage in self-censorship in order to maintain legitimacy in the largely rationalization-oriented organizational field.

#### *8.4 The role of additional organizational factors*

There are obvious organizational factors that might shape organizational programming and investments and thereby might confuse interpretation of the assessment of the effect of cognitive proximity in particular. For example, the investments and activities of organizations might be in specific ways related to the size of the organization. In large organizations there might exist internal organizational demands that influence response. Old and complex organizations are known to be particularly resistant to changing (Hannan and Freeman 1984). And as Weber has noted, because bureaucracies have a tendency to grow, the effect might be especially pronounced in large, public agencies. We might have indication of this mechanism in the many public organizations in the knowledge-practice gap, where problem recognition does not necessarily lead to response. However, it is especially in these, where detailed knowledge and understanding of agro-ecological



farming practices is demonstrated. And since such knowledge appears to be a prerequisite for adaptive social response, the amount of pre-existing resources in large, old, and complex organizations might present an opportunity to engage the potentially costly experiments prevention-oriented farming practices might demand. In this study, when looking at the four organizations studied that both theoretically acknowledge the potential of prevention-oriented farming practices and practically work to institute them we find that they vary dramatically in size.

### *8.5 Limitations of the study*

#### *8.5.1 Lack of ecological data*

The work presented here does not include any ecological measures and is relying entirely on measures of social inputs and outputs. Disaggregating these social data by geographic proximity shows some degree of adaptive response, that is, the existence of prevention-oriented programs in Iowa. This adaptive social response, however, has not translated into actual changes in farming practices according to a recent USNRCS (2010) report. The report showed that prevention-oriented farming practices were markedly missing from the regions most contributing to pollution. We therefore argue that it is important for future research to incorporate ecological measures into the study of social adaptive response. This is especially important in cases where external “reality checks” as published by USNRCS (2010) do not exist.

#### *8.5.2 Lack of time series data*

The data on resources and programs presented are cross-sectional. This has the drawback of not speaking to the inherently temporal nature of adaptation. Time-series data would be more valuable for understanding change over time in resource mobilization and programming. Further, such data would allow the exploration of the relationship between resources and programming. There exist two general strategies to obtain such data. First, organizations can be revisited at intervals for quantitative data collection in order to provide ongoing updates. Alternatively, archival organizational and published material can be collected and combined with narrative accounts of organizational respondents to draw a picture of the adaptation over time.

## *9. Conclusion*

In this study we present a search for factors shaping adaptive social response of organizations to ecological risks. Our assumption was that the recognition of the major threat excess nitrogen constitutes to future human well-being, in combination with an overall increased awareness of ecological risks, should lead to a measurable adaptive response in the organizations working at the intersection of farming and water quality. We conceptualized adaptive response as resources investment in prevention-oriented organizational programs. We included measures of geography and cognition in order to explain opportunities for and obstacles to prevention-oriented programs at the level of the organizational field that may be “adaptive” in the sense of supporting sustainability in the MRB farming sector.

We show that the organizational field is a critical unit of analysis in studying adaptation to institutional environmental demands. At an organizational level, the resource-based perspective provided the necessary tool for a fine-grained presentation of resource investments in intervention strategies. The proximity framework served to aggregate organizational information meaningfully at the level of the organizational field. The vast majority of analyses undertaken to understand the environmental transformation of the farming sector are focused on individual farmers, and there is insufficient attention to the systemic aspects of innovation or lack of innovation as demonstrated in this analysis. Our approach is an extension of previous studies in that it combines organization-level inquiry with geographical and cognitive considerations at the level of the organizational field.

As such, we go beyond the structural mapping of resources and attempt to explain the patterns observed. A focus on proximity moves analysis away from the assumption that organizations in a field are all subject to the same institutional demands and are able to respond to such demands at the same rate. As the ecological is contextual, so, too, are organizations, even in a global economy. The proximity approach acknowledges the fact that pollution is produced, distributed, and mitigated unevenly across the biophysical landscape and among social actors (Nowak et al. 2006). An approach taking into account the geography of the landscape

and the cognition of social actors is indispensable when trying to understand and optimize adaptive social response to ecological risks.

The paper critically extends previous work by incorporating cognition into the analysis of resource allocation. In explaining variation among organizations we use cognitive proximity as a mediating variable throughout the paper. However, in explaining the prevention-orientation of organizations cognitive proximity can equally well be seen as an intangible organizational resource as discussed in the introduction and in section 3.2. As such, our findings indicate that cognitive proximity to the intervention logic of prevention has a very limited effect on the actual organizational program types of the organizations interviewed. Rather, we observed a notable “attitude-behavior gap” in the interviewed organizations. This observation supports the hypothesis that actual obstacles to adaptive behavior exist in the interviewed set. The question remains whether agency capture and self-censorship, based on isomorphic pressures in the organizational field, are hindering even prevention-oriented organizations from allocating resources towards prevention-oriented programs.

The widely supported rationalization-oriented programs have a place in addressing pollution issues in the short term. However, the ongoing, almost exclusive investment in rationalization programs to date reinforces a status quo that might prevent a serious testing of preventative intervention strategies. Such testing under a range of real-world biophysical, social and economic conditions at a large scale would be necessary for adaptively moving towards sustainability in the farming sector of the Mississippi River Basin.

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## CHAPTER 4

# LIMITS TO LEARNING: UNDERSTANDING OPPORTUNITIES AND CONSTRAINTS FOR AGRO-ECOLOGICAL REFORM IN THE MISSISSIPPI RIVER BASIN THROUGH ORGANIZATIONAL ECOLOGY

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### *Abstract*

This paper highlights the limits of organizational learning for the study and management of natural resources and introduces organizational population ecology as a complement. Where established organizations lack the ability or will to change, new organizations might accomplish improvements. To illustrate this claim, the paper assesses the ecological orientation of programs aimed at addressing hypoxia in the Gulf of Mexico in organizations founded, or “born,” at different time points. Based on interviews with 40 regional, state, and national organizations in the Mississippi River Basin farming sector, the paper shows that more recently founded organizations carry the majority of ecologically-oriented programs, while relatively longer established ones lack them. The findings stress that learning is difficult and incomplete. Attending to changes at the level of organizational populations as a complement to learning at the level of the individual organization can advance a political and scholarly debate about the greening of agriculture.

### *1 Introduction*

Organizational change for environmental improvements is predominantly studied and understood from a perspective of learning and incremental change. Social learning, collaboration, and participation are dominant themes in environmental science, natural resources, and rural sociology. These approaches assume a stable population of organizations and that existing members of this population are willing to and capable of

changing sufficiently to meet new societal demands. What these studies ignore are the limits of learning. These limits refer to the inertia people and organizations exhibit when it comes to doing things in ways that run counter to their personal or organizational historic behavior (Burns and Stalker 1961; Hannan and Freeman 1977). Organizational population ecology, also known as organizational demography, claims that change is “difficult and incomplete” (Brechin, personal communication). Instead, organizational population ecologists stress that social change occurs at the level of populations of organizations: organizations that no longer fit changed environments “die” and new ones that do fit are “born” (Carroll and Hannan 2000).

At the core of this paper I therefore argue that the sociology of natural resources needs to attend to the question of change at the level of populations of organizations, that is, groups of organizations with similar structure and goals, as much as it does to changes at the level of the individuals and individual organizations. These complementary approaches, taken together, constitute a full-fledged theory of organizational adaptation and change. In such a theory, organization-level changes promote variation among organizations, making them more or less prone to external selection pressures. Where existing organizations cannot or will not meet new demands, new organizations could emerge or could be actively encouraged to meet new demands through political intervention. At the same time, older organizations might become obsolete in face of changing demands and disband—or “die”.

I test the specific assumptions about organizational turnover and environmental improvements in the case of the “dead zone” in the Gulf of Mexico. The dead zone, a low-oxygen or hypoxic zone in the Gulf of Mexico is primarily caused by nitrogen fertilizers leaching from farm fields in the far-away upper reaches of the Mississippi River Basin (MRB) (EWG 2006; USEPA 2008). To assess adaptation to new ecological demands and to advance research on organizational adaptation for sustainability, I analyzed in an empirical case the distribution of ecological programs based on organizational age. I derived a typology of technical responses that organizations engage in, and used it to assess the ecological orientation of programs in organizations founded, or “born,” at different points in time. Based on interviews with 40 carefully selected regional, state, and national organizations in 2007, I expected a clear answer to the question: Does agro-ecological reform

occur in established organizations or through the birth of new organizations? I hypothesized that those organizations which were founded relatively more recently would carry the majority of ecologically oriented programs, and that those relatively longer established organizations would lack the ability or willingness to implement such programs. I present results as descriptive statistics and narrative interview data. In conclusion I argue for the importance of attending to changes at the level of populations of organizations as a complement to learning at the level of the individual organization. Only in complement will these approaches allow us to “push the new frontiers that are afforded to us by the environmental domain” (Bansal and Gao 2006: 473).

## ***2 Theory***

### *2.1 The role of organizations in agriculture*

While the farming practices to curb nitrogen leaching are implemented at the farm level, farmers do not operate in a vacuum; much of the individual farmers’ activity is based on know-how neither produced nor producible by an individual farmer. Rather, knowledge and skills exist spread out across organizations (Savage 1994; Moore 2008). Organizations and constellations of organizations play key roles in the production as well as remediation of environmental pollution (Perrow 1997). According to Shwom (2009), environmental sociology can therefore benefit from addressing the role of organizations in studying environmental degradation and improvements. Considering organizations ranges between an a-political and reductionist approach that focuses on the behavior of individuals in explaining complex social outcomes on the one hand (Schneiberg and Clemens 2006), and higher-level political-economic theorizing ignorant of the agency of individuals and individual organizations on the other. An organizational focus takes seriously the embeddedness of individuals, for example the individual farmer, in larger political-economic contexts that shape, mediated by organizations, individual opportunities and constraints (Bell 2004).

### *2.2 The limits of organizational learning*

In organizational studies applied to the environment, a focus on learning and adaptive change is common. As

Primmer and Wolf (2009: 2) put it:

“There is tremendous interest in adaptive management, learning, and innovation in support of sustainability... Adaptation is seen as largely dependent on social learning. Within this academic tradition, there is a high appreciation of participation, trust building, and deliberative competence in keeping with contemporary notions of governance (Lebel et al. 2006; Tàbara and Pahl-Wostl 2007; Armitage et al. 2009).”

This trend continues and is illustrated by a 2009 special issue titled “Living with Environmental Change: Adaptation as Social Learning,” published by the journal *Environmental Policy and Governance*, as well as a stream of individual publications over a range of journals, but especially in *Society and Natural Resources* (Carr and Wilkinson 2005; Collins and Ison 2011; Legun 2011; Padmanabhan 2011). In the dominant learning framework, getting the “how-to” of learning right promises to bring forth needed changes (Armitage et al. 2009). However, Watzlawick (1983) identifies “more of the same” as a sure way to perpetually remain locked in an unhappy situation. In the case of learning for change this means that there is a chance that more collaboration, more participation, and ever better understanding of learning mechanisms might not be sufficient to move beyond the status quo.

Approaches such as social learning, collaboration, and participation assume that individual members of stable populations have the ability and willingness to adapt in face of ecological risks. However, old incumbents might not be willing or able to change and new organizations might be needed that can accomplish improvements (Scott 2002). Scholars of learning therefore ought to be open to the notion that “change is difficult and incomplete” (Brechin, personal communication) and that understanding processes at the level of populations of organizations will complement those of learning at the level of the individual organization or among organizations. An organizational population is an “aggregate of organizations” that “must be alike in some respect” (Hannan and Freeman 1977: 934). In addition, these organizations co-exist in a shared system of study: “Systems relevant to the study of organization-environment relations are usually defined by

geography, by political boundaries, by market or product considerations, etc.” (Hannan and Freeman 1977: 936).

### *2.3 Key concepts of organizational ecology and organizational population ecology*

In organizational ecology, variation among organizations makes some more apt to survive in a given institutional environment, others less so. When environmental conditions change, as is the case when new societal demands call (for example) for improved environmental performance, selection, theoretically, will favor organizations that deliver based on these demands. All others will suffer and eventually disband (Carroll 1985; Hannan et al. 2007). Organizational ecology and its evolutionary imagery include logics of learning at the level of individual organization. Organizational population ecology challenges this notion of learning and adaptation at the level of the individual organization. In contrast, organizational population ecology postulates “that adaptation of organizational structures to environments occurs principally at the population level, with forms of organization replacing each other as conditions change” Hannan and Freeman (1977).

#### *2.3.1 Organizational age and organizational inertia*

Hannan and Freeman (1989) point to the dual nature of reflexive organizational change: while change might lead to increased fit with an organizations environment, it also poses a risk (Levinthal 1991). According to Hannan and Freeman (1989), a change in an organization’s internal processes may be disruptive to a point where its survival is at risk. Hannan, Polos and Carroll (2004) argue in detail that because benefits stemming from organizational change do not systematically exceed associated risks, selection mechanisms favor structural inertia in organizations. In short, remaining the same is the norm, changing the exception among organizations in a given field. This effect is especially pronounced in organizations of old age and high complexity, because of the increased time needed to reorganize structures (Hannan and Freeman 1984). Change within an organization can therefore not be expected to flow naturally or easily from actual or expected changes in its environment, but must be weighed against the risks it poses to the organization and the benefits of adhering to a status quo. In fact, in situations of high perceived risk contained in changing, in

face of threat or adversity, adaption is especially unlikely, described as “threat-rigidity effect” (Staw, Sandelands and Dutton 2004).

This rational reason for inertia is complemented by other, more cultural and historic ones.

Aside from deliberate decisions to change or resist change, Huber (1991: 91) summarizes that

“the nature of an organization is greatly influenced by the nature of its founders and its founding (Stinchcombe 1965; Kimberly 1979; Schein 1984; Boeker 1988, 1989). What an organization knows at its birth will determine what it searches for, what it experiences, and how it interprets what it encounters.”

This phenomenon is central in Selznick's classic work “TVA and the Grass Roots”. “TVA and the Grass Roots” that describes in detail the creation and work of the water management organization Tennessee Valley Association:

“Selznick emphasizes that an organization develops a mission and a set of routines in its early years, in a process of cooperation and cooptation with key environmental actors that the agency depends upon to get things done, and that this mission and routines then crystallize as an organizational identity that can’t be easily changed”. (Strang, personal communication)

This phenomenon is known in organizational ecology as “founding effect” and it inhibits changes that are too radical a departure from the conditions and assumptions at the time of founding (Stinchcombe 1965). These assumptions and associated organizational culture and routines have become taken for granted, and passed on over time (Tolbert and Zucker 1996). Routines are for organizations what for people have been termed “habits of the heart” (Bellah et al. 1985; Tocqueville 2000): culturally and cognitively engrained ways of doing that make change undesirable, impossible, or altogether inconceivable. Any kind of inertia, whether based on an unwillingness or inability, rational or cultural, of existing organizations to change, poses an opportunity to emerging actors, who might take on tasks in a changing environment that existing organizations may be reluctant to do.



### *2.3.2 Density effects*

Once new actors have emerged and become recognized, they have, de facto, created legitimacy for this kind of organization, thereby making it first easier and eventually necessary for other organizations either to follow suit or to be delegitimized and eventually to disband. This process leads to a homogenization of the organizational landscape (DiMaggio and Powell 1983). Also, the more organizations of a certain kind are established, the easier it will be for others of the same kind to establish themselves, because the struggle for legitimacy—and with it, resources—has been won. This is known as the density dependence of organizational emergence (Hannan and Freeman 1977).

### *2.4 Interdependence of learning and turnover*

Learning and organizational replacement are not mutually exclusive but interact significantly (Lewin and Volberda 2003). From an organizational theory perspective, failure of learning due to inertia creates space for new entries. In turn, new entries create opportunities for learning. I don't argue that an organization could learn enough to achieve within itself the changes that one might see elsewhere in an entirely new organization.

### *2.5 Imbalance in the study of learning versus turnover*

To date an organizational ecological approach is under-developed in the literature on ecological transformation of natural resources sectors. In popular journals of environmental, natural resources, and rural sociology, an imagery of adaptation at the level of the individual and the individual organization through mechanisms such as learning, collaboration and participation abounds. Table 6 juxtaposes search term results for articles with a “learning logic” and with a “turnover logic”. Table 6 illustrates that the “learning logic” dominates in all journals. In Environmental Policy and Governance and in Society and Natural Resources, the imbalance is most pronounced.

Table 6 Imagery of adaptation at the level of the individual/ individual organization through mechanisms of learning, collaboration and participation (learning logic) and adaptation at the level of populations of organizations (turnover logic) in popular environmental sociology, natural resources and rural sociology journals

	Search term	AHV <sup>1</sup>	E&S <sup>1</sup>	EPG <sup>2,3</sup>	O&E <sup>1</sup>	RS <sup>4</sup>	SNR <sup>1</sup>	SR <sup>1</sup>	All searched journals
Learning logic	Adoption	21	11	1	3	7	15	5	
	Collaboration	8	31	1	4	1	47	1	
	Learning	21	59	8	5	5	38	4	
	Participation	25	51	17	4	18	134	17	
	Sub-Totals	46	110	25	9	23	172	21	406
Turnover logic	Competition	10	9	0	1	6	3	3	
	Evolution	7	0	1	9	4	12	6	
	Selection	12	17	0	5	1	7	1	
	Survival	9	16	0	3	5	6	7	
	Sub-Totals	38	42	1	18	16	28	17	160
	Total	113	194	28	34	47	262	44	722
	Turnover logic in % of Total	34%	22%	4%	53%	34%	11%	39%	22%

Key:

AHV Agriculture and Human Values  
E&S Ecology and Society  
EPG Environmental Policy and Governance  
O&E Organization and Environment<sup>1</sup>  
RS Rural Sociology  
SNR Society and Natural Resources<sup>1</sup>  
SR Sociologia Ruralis

- 1) Web of Science years 2000-2011, Topic search
- 2) ISI All Databases 2009-2011, Topic search
- 3) New in 2009
- 4) Wiley online 2000-2011, Abstract search

Actual studies that consider organizational turnover at the level of organizational populations are rare. Porter (2006) discusses organizational ecology theoretically as one aspect of coevolution of organizations and the natural environment. Shwom (2010) includes it in her call for incorporating organization theory into environmental sociology. Empirical applications of the concept are also rare. McLaughlin and Khawaja (2000) use organizational population ecology to study domestic environmental movements, and Murphy (2005) uses

the same concept to study transnational ones. Wolf and Hufnagl-Eichiner (2007) study the emergence of forest landowner cooperatives, Stretesky et al. (2010) the density dependence of natural resources violations.

The lop-sided focus on change through learning and collaboration means that the limits of learning and the potential need for organizational replacement to achieve lasting improvements are largely unknown terrain. This thesis is implicitly acknowledged in a recent special issue on “Agrifood movements and the role of rural sociologists” published by the journal *Rural Sociology*. The introductory article exemplifies a “learning logic”, stressing reflexivity, trust, and collaboration between scholars and activists to strengthen an alternative agrifood movement (Friedland, Ransom and Wolf 2010). A follow-up article, however, introduces another avenue for change, namely, the formation of a new organization, “Agrifood Researchers without Borders” (Friedland 2010). Friedland (2010) promotes this new organization as a complement to collaboration within the agrifood movement. However, Friedland’s (2010) treatment of the new organization is purely pragmatic or promotional. He does not explicitly theorize a need for transformations at the level of populations of organizations—that is, the need for new organizations to do new things and the possibility of “death” for old incumbents.

In order to explicitly theorize such a need this paper calls for complementing the learning approach, not supplanting it, with approaches that take into account constraints, be they political or organizational, to adaptation to new environmental demands. The organizational ecological processes and organizational learning process currently are not on equal footing. In this study I therefore show the utility of an organizational ecological approach that addresses population-level processes as a complement to a focus on learning and collaboration in supporting sustainable development in agriculture. The focus on organizational ecological processes holds potential to better understand and manage inevitable as well as necessary ecological changes in the current farming system in the Mississippi River Basin.

### *3 Case*

### *3.1 Ecological disruption in the Mississippi River Basin*

A nearly single-minded effort to maximize agricultural production has led to ecological dysfunction in the Mississippi River Basin (Atwell et al. 2008). The poster child of ecological destruction in the Basin is the “dead zone” at the mouth of the Mississippi River in the Gulf of Mexico. The Mississippi River drains an expansive area of former prairie ecosystems, which has been transformed into one of the major grain baskets of the world. The region delivers water to the Gulf of Mexico where, every summer for the past several decades, an area of decreased oxygen (a hypoxic zone) has developed. In the Gulf, hypoxia has altered marine ecosystem structure and functioning (NSTC 2000) to a point where only “limited recovery following abatement of oxygen stress” is possible. (Rabalais, Turner, and Wiseman 2001:327). The overwhelming scientific evidence points to disproportionately small geographic areas with intensive farming systems in the upper reaches of the Mississippi River Basin as the main source of the pollutants, primarily nitrogen, causing hypoxia (USEPA 2008; David et al. 2010). Reducing nitrogen leaching losses from the sub-basins of the upper Midwest is therefore critical to reducing total nitrogen loading in the Gulf of Mexico (Diaz and Rosenberg 2008).

### *3.2 Ecological farming practices as a solution to Gulf hypoxia?*

The challenge of efficient nitrogen fertilizer management in conventional, industrialized agriculture has been defined in terms of rationalization: how, when, and where to apply these highly reactive forms of nitrogen in order to mitigate losses to the environment. *Fertilizer-based* approaches are eco-efficiency approaches, efforts to make outcomes “less bad” (Wolf and Buttel 1996). In terms of effectiveness, Randall et al (1997) find that conventional annual crops cannot consistently prevent reactive nitrogen from leaching out of the field at safe drinking water levels below 10mg of nitrate per liter.

In contrast, there exist practices that have been shown to systematically improve nitrogen retention up to 100 percent. These practices can be broadly categorized as *agro-ecological* as they rely on biological processes in

agroecosystems. For example, carbon and nitrogen cycle together in natural ecosystems through photosynthesis, decomposition, and transformations in the nitrogen cycle carried out by microorganisms. Management practices that support carbon and nitrogen cycling together include reducing the length of periods without ground cover (e.g., planting winter cover crops), returning crop residues to the soil, increased reliance on biological nitrogen fixation, and increasing perennial crops (e.g., forage legumes and grasses, woody species and perennial grains and vegetables) (Drinkwater and Snapp 2007). The effectiveness of these practices is well documented from the point of view of pollution prevention and agricultural productivity (Clark et al. 1998; Drinkwater et al. 1998; Gardner and Drinkwater 2009). These practices reflect a logic of pollution prevention and fundamental system redesign (Hawken, Lovins and Lovins 1999).

In addition to addressing the ecological dysfunction of industrial farming systems, studies exist that indicate that social and economic benefits also stem from the introduction of agroecological practices into the region: Jordan et al (2007: 1570) summarize that the “benefits included social capital formation, greater farm profitability, and avoided costs associated with specific environmental damages.” In the sustainable management literature, MacRae et al. (1990) consider rationalization approaches in agriculture as “low sustainability” approaches that will not be able to shift farming conditions sufficiently to reduce or even halt high levels of ecological destruction. In the literature on transition management, Loorbach (2007) argues that current problem solving strategies tend to be short-term and incremental, with a focus on optimizing existing systems as do rationalization approaches, rather than creating new ones, as introducing agro-ecological farming systems. Loorbach draws an analogy between rationalization approaches, such as the fertilizer-based approaches in this study, and the kind of old thinking Einstein refers to in his famous quote that “we can’t solve problems by using the same kind of thinking we used when we created them”.

The emphasis given here to agro-ecological practices is not meant to downplay the costs and risks associated with introducing them to produce acceptable yields under diverse biophysical, climatic, social and economic conditions. However, contrasting them with fertilizer-based approaches allows to assess organizational

response of organizations in light of the goal of achieving sustainability of farming systems, not only remediating Gulf hypoxia.

#### ***4 Research question and hypothesis***

The widespread adoption of agro-ecological practices in response to water pollution in the Gulf of Mexico would constitute such a radical departure from the status quo, I argue, that it could not be fully met through adaptation at the level of existing organizations; rather, more radical changes at the level of populations of organizations would also need to take place. In short, I hypothesize that inertia inhibits old incumbents to embrace change. Rather, agro-ecological change as a response to Gulf hypoxia can be primarily attributed to new organizations that can do new things in new ways. If I find support for my claim, scholars of organizational adaptation need to take seriously organizational inertia and consider the role of organizational birth and death as a complement to organizational learning, in order to understand and support agricultural reform. To test my claim, I ask the question: How does agro-ecological reform map onto the age of farm support organizations? I expect agro-ecological reform, measured as agro-ecological programs initiated in response to nitrogen leaching and Gulf hypoxia, to be carried out by relatively recently founded organizations due to the inertia-causing mechanisms.

#### ***5 Methods***

##### ***5.1 Selection of study sites and organizations***

Given the rarity of the phenomenon under study, I used a purposeful selection strategy to choose sites and organizations that would yield an information-rich group of interviewees (Patton 2002). Site selection was guided by considering the disproportionate role of a few states within the Mississippi River Basin as pollution sources, namely Iowa, Illinois and Indiana. In these states, support for agro-ecological practices as a response to basin-wide water pollution concerns is very rare. As a professor at a university in Illinois, whom I consulted for advice on site selection, said, “There are just no such organizations here.” Iowa, in contrast, is

home to some well-established organizations that explicitly support agro-ecological farming practices to reduce nitrogen leaching and Gulf hypoxia. As such, Iowa constitutes a “most likely” case (Flyvbjerg 2004), that is, a case in which I was more likely than elsewhere in the Corn Belt to find organizations engaged in agro-ecological programming. Another most-likely case is Louisiana. Hufnagl-Eichiner et al. (2011) have found that in comparison, Louisiana invests disproportionately to its contribution to Gulf hypoxia in agro-ecological research, indicating that Louisiana organizations are rather keenly aware of the pollution in their “backyard.” Iowa covers a land area of 145,743 square kilometers with a population of three million. Louisiana covers 51,885 square kilometers and has a population of four million. The states are archetypes in that Louisiana is where the Mississippi River flows into the Gulf of Mexico and where the hypoxic zone is located, and Iowa is the country’s largest corn producer (Figure 7).

In both states I selected organizations that in 2007 were working to address the problem of Gulf hypoxia through changes in the farming sector. I selected a first set of respondents from news releases and expert opinions and continued to search for organizations in situ until redundancy was achieved. I supplemented these state-level data with data from interviews at the regional and national levels in order to potentially falsify findings made at the state level at a broader level of social organization—at the levels of the Mississippi River Basin and of the nation state. Organizations include federal and state government agencies; non-governmental organizations concerned with farmer interests, the environment and water quality; university and extension agencies; and private service providers.

## *5.2 Interview process and analysis*

I conducted 49 semi-structured interviews with representatives of 40 organizations in 2007, as well as periodical update check-ins with selected organizations to stay aware of ongoing changes since the end of the fieldwork in 2007. The interview guide contained questions addressing organizational demographics, organizational history, and organizational programs pertaining to nitrogen management and water quality. All

interviews were transcribed and coded in Atlas.ti. I supplemented respondent narratives with documentation provided by respondents, and by that publicly available through media.

I relied on descriptive statistics--that is, a stem-and-leaf plot--for quick assessment of the association between organizational founding year and ecological programming. I categorized organizations as following one of the farming system logics introduced above: a fertilizer-based logic (F), or an agro-ecological logic (A). Of the few organizations pursuing agro-ecological programming, some pursued agro-ecological logics alongside rationalization logics. Whether an organization had only agro-ecological programming or whether it engaged in “multitasking,” I categorized all these organizations as “agro-ecologically oriented” (A). Just as in the case of state selection, if this methodological decision introduces a bias, that bias would be toward finding a shift towards sustainable agriculture in the organizations under scrutiny, increasing the likelihood of falsifying my hypothesis.

## **6 Results**

### *6.1 Founding period and program orientation*

There is a clear relationship between organizational age and the choice of agro-ecological programming as a response to Gulf hypoxia. In summary, none of the interviewed organizations founded before 1986 promotes agro-ecological farming practices in general or perennial plant systems specifically as a response to Gulf hypoxia. Of the interviewed organizations, agro-ecological systems were promoted as a response to Gulf hypoxia exclusively by organizations founded in 1986 or later.

Table 7 summarizes founding years and programming orientation, distinguishing those organizations following a fertilizer-based logic (F) from those following an agro-ecological logic (A).



Table 7 Founding period and program orientation

	Founding period	
FFFFF	1995-2005	A
FFFFFF	1985-1994	AAAA
FFFFFF	1975-1984	
FFFF	1965-1974	
F	1955-1964	
FFF	1945-1954	
F	1935-1944	
FF	1925-1934	
FFF	1915-1924	
	1905-1914	
FF	<1904	

Depicted are results of interviewed organizations founded between 1871 and 2005 that operate in Iowa (17), in Louisiana (12), at the regional Mississippi River Basin level (5) and at the national level (6). Five out of the 35, or 14 percent, have agro-ecologically oriented programs as a strategy to reduce nitrogen leaching and associated Gulf hypoxia. Four of these were founded in the ten-year period from 1985 to 1994: one in 1986, two in 1987, and one in 1989. One other organization interviewed with agro-ecological programs, operating at the regional level, was founded in 2004. No organization founded later than 2005 was contained in the set of organizations interviewed.

## 6.2 *Soil erosion and surface-run off*

Across all interviewees, controlling soil erosion and surface run-off emerged as the major focus, even though the effect on water quality of these approaches is moderate in comparison to preventing nitrogen from leaching through the soil profile and leaving the field through drainage lines (David et al., 2010) or avoiding the application of nitrogen in a radically re-designed perennial system. One respondent from a state agency gave a potential explanation for the rarity with which organizations adopt agro-ecological practices:

“At least ninety percent of our work deals with surface run-off, based on our tradition [of] sixty years of soil conservation work. Pollutants coming out of tile line have only been a recent, not a discovery, but something that we will acknowledge as a state recently.”

### *6.3 Beyond birth date – the characteristics of the agro-ecological organizations*

All organizations classified “agro-ecological” operate (by now) at the regional level. Three originated and are headquartered in Iowa, one has a branch location in Iowa and is headquartered in Minnesota, and one is headquartered in Minnesota. Their agro-ecologically oriented programs include political advocacy to increase support for perennial agriculture, applied research into the use of cover crops, a cover crop information exchange, and on-farm trials with cover crops and perennial crops. The organizations supporting these programs vary vastly in their resource base. One of them has the highest budget and the most persons allocated to address nitrogen relevant programming of all organizations interviewed, while another has only a fraction of a dedicated staff position and no dedicated nitrogen-relevant budget at all. The other three organizations lie in between. The mission statements of all of these organizations do stress both agricultural production and sustainability. Further, all of the representatives of these organizations talked in detail about their knowledge about agro-ecological farming practices. This accords with the fact that they also support agro-ecological programs.<sup>2</sup>

## **7 Discussion**

### *7.1 Theoretical implications*

Programs supporting agro-ecological practices as a response to Gulf hypoxia exist in a cohort of organizations founded during a narrow intermediate past with a peak in the late 1980s, and are completely absent in any organization founded before 1984 (which is the majority of organizations interviewed). This

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<sup>2</sup> The reverse, however, is not true; that is, elsewhere I find that agro-ecological knowledge does not automatically lead to agro-ecological programming, however, it is a prerequisite (Author et al., unpublished manuscript).

study illustrates the merits of a population-level view to understanding agro-ecological reform. That none of the relatively older organizations has made the move to agro-ecological programming is in stark contrast to notions of institutional pressures and the ability of organizations to learn. It is, however, in line with notions of organizational inertia and the importance of founding effects. This study confirms organizational age as a key variable in shaping programs at the state, regional, and national level and therefore contributes to the much-called-for mid-range approach in environmental sociology, looking at variables “that are expected to exert an influence in more than one setting” (Freudenburg and Gramling 1994:5).

## *7.2 Political implications*

For the practice of agro-ecological reform, the results raise a couple of important questions: Do the observed new entrants represent the beginning of a wave of agro-ecological reform? Or was there a distinct window of opportunity during US agro-environmental history that gave rise to a class of organizations that were not present before and after? The following quote of a state actor about organizations that aggressively push for agro-ecological reform supports the latter possibility of a short window in time:

“You know, I don’t have many constraints... we used to 20-25 years ago, ...the voters, the Sierra Club, all kinds of groups, we have very little of that any more... Those people that felt that way [about radical agro-ecological reform] either got moved out of those jobs or they retired...

This quote indicates that the foundings in the mid-to-late 1980s might be left-overs of the environmentalism peaking in the United States in the 1970s. This assessment would be in line with detailed considerations of founding effects, namely, that

“there invariably exists a time interval between when an organization is first conceived of and the rather arbitrarily defined birth event (when, for example, an organization is "incorporated"...)  
(Huber 1991: 91)

The window of opportunity explanation is also confirmed by Mitchell et al. (1990) who find clear waves of organizational foundings and distinct themes associated with different eras in the US environmental movement.

In organizational ecology and political economic studies organizational inertia is well recognized. Multiple studies find strong empirical evidence that organizations do not change much, that they do not easily adopt new technologies, especially those that destroy core competencies as might be the case with prevention-oriented agro-ecological farming practices, and often fail when they try to be adaptive (for recent empirical evidence in other industries see Majiid et al 2011, Koch 2011, Steinback et al 2010). Strang (2010) finds in a large benchmarking study of corporate banks that managers recognize and use the logic of structural inertia “when they commonly seek to create new subunits and businesses to take on new agendas, rather than laboriously reconstruct the agendas of old and difficult to change units” (David Strang, personal communication). In addition, “a high level of technological capability impedes explorative innovation” in organizations (Zhou and Wu 2010). This observation might explain why established organizations with specific technological capabilities are so resistant to embracing change. The quote by a state agent making the distinction between recognition and acknowledgement of an environmental problem and linking this distinction to the state agencies history of soil erosion capabilities illustrates this point.

### *7.3 Methodological considerations*

With respect to organizational mission, to produce Table 7, actual interview data were used in which organizations describe their programs, triangulated by documents and web presentations detailing these programs. Many of the organizations interviewed, especially those founded in the period after 1975, have mission goals that strive to integrate agricultural production with ecological conservation and sometimes with social justice as well. Collecting data on actual programs, not just on written missions, demonstrates that despite existing widespread mission statements referring to the merits of agro-ecological practices, few organizations pursue them in their actual programs.

#### *7.4 Limitations of the study*

The study was conceived and conducted as an effort to analyze and understand social response to a pressing ecological problem, Gulf hypoxia. Some organizations interviewed have in the time since 2007 included programs for the promotion of agro-ecological farming practices, namely cover cropping. One program especially stands out. Legally, it is a collaboration of university extension, state and industry partners, some of the oldest organizations in the interviewed set. „In name,“ however, a respondent states, „we are more like an organization.“ The existence of this quasi-organization is in accord with the introductory notes that learning and turnover are complementary and that the emergence of new organizations might create legitimacy for established organizations to change through learning. It is, however, also in accord with the notion that change is difficult and incomplete. Incomplete especially because the interviewees affiliated with this program are explicit about the fact that addressing Gulf hypoxia was at no time part of their collaborators' goals. In fact, a relation between agriculture and Gulf hypoxia is to this date not acknowledged in the programs mission or materials. Hypothetically, this lack of acknowledgement might constitute a necessary prerequisite to secure support from the highly institutionalized state and industry partners, as the one quoted above, that will not lend support to organizations supporting radical agro-ecological reform based on the notion that the dominant mode of farming is responsible for Gulf hypoxia. Further research could speak to the question whether this quasi-organization might constitute a case in which a new entrant with potentially radical undercurrents is pursuing its agenda not through “systemic change”, but through “skillful performance along conventional lines” (Strang and Sine, 2010).

#### ***8 Conclusion***

This study highlights the important processes of organizational turnover in complementing those of organizational learning. In this study the inertia of established organizations appears to be a true obstacle to change. The study shows that organizations with agro-ecological programs emerged only during a very

narrow window in time in the late 1980s, possibly as a belated consequence of the post- Earth-Day enthusiasm of the 1970s rather than as the beginning of a new era.

We live in an era in which, thanks to hospitals and nursing homes, the processes of birth and death are unfamiliar to most of us. And according to popular wisdom, we fear what we don't know. This is true at the personal as well as at the public and organizational levels. I need only reference a "too big to fail" slogan to illustrate our society's fear of failure. We observe within our society a great determination to amend, twist, and change existing institutions to fit new realities, rather than a willingness to let go of the old in order to embrace new organizations that might do necessary new things for us. Having said this, and despite the strict population-level focus of the study presented, I reiterate that my goal is not to discredit aims to explore and understand learning or management efforts. Rather, my initial claim remains that population-level processes are always a complement to institutional processes in a coevolutionary view of organizational adaptation.

In conclusion, I therefore advocate a research agenda that explores population-level processes as a complement to the organizational learning approaches that, to date, dominate the field. These studies could take the form of historic time series of foundings and deaths of organizations similar to those presented in this paper. Alternatively, they could analyze the transformations that bureaucracies undergo to sort out how much learning can achieve and whether better understanding of and greater investment in the creation of new organizations is necessary to achieve sustainability goals.

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## CHAPTER 5

### SYNTHESIS

#### *Competition and complements: Institutional theory, resource-based theory, and proximity*

One of the premises of this dissertation is that the recognition of ecological risks, such as excess nitrogen, should lead to an adaptive social response that can be analyzed, understood and improved through interdisciplinary scholarly research. This dissertation aims to identify useful concepts for the study of social-ecological adaptation, operationalize variables that can explain variations in adaptation, and describe in detail the processes shaped by these variables in the context under study. The hypoxia in the Gulf of Mexico, caused by leaching of nitrogen from farm fields in the upper reaches of the Mississippi River Basin, served as a case on which to study these assumptions. In conclusion, this dissertation successfully analyzes social-ecological adaptation at the federal, state and organizational levels. The understanding of the processes underway, resource investments and program formulation, and the factors influencing these processes, cultural-cognitive and geographical proximity and organizational age, serve to conceptualize, record, analyze and understand this response. As such, the work presents specific mechanisms, some intuitive, some surprising, by which the recognition of current and future risks associated with excess nitrogen, and an overall increased awareness of ecological risks, shapes social response.

Much of institutional theory has its focus on legitimacy challenges without paying attention to their technical and material consequences. To strengthen a material resource-based view within institutional theory, this dissertation takes seriously the difficulties faced by social actors when translating changed institutional demands into organizational behavior. Specifically, this dissertation examines the resource investments in response to social demands. It also pays attention to key variables which shape the context of resource investments, as well as the effect of resource investments on organizational environmental outputs. The proximity approach makes it possible to go beyond previous work on organizational resource allocation,

inasmuch as it provides a framework for conceptualizing variation among actors and actor constellations studied. As such, it can be used in a broad range of cases in which endogenous and exogenous components interact to produce – or hinder – sustainability transitions.

This dissertation, particularly chapter 2, rests on rather rationalistic assumptions: Finding evidence for the chain of causality argued by Wolf and Primmer (2006) and further detailed in chapter 3, that is to say that social demands stimulate resource investments (chapter 2), which in turn increase organizational capability to produce environmental outputs (chapter 3 and chapter 4). The analysis of resource formation in relation to proximity highlights the ways and the extent to which this hypothesized causality does or does not present itself in the empirical analysis. That it often tends not to unfold will not come as a great surprise to institutionalists used to studying non-rational phenomena – which are best explained by the notion of embeddedness.

Therefore, the proximity framework is a formal attempt to extend previous work by attending to both rational and non-rational elements of social behavior. Chapter 3 is a departure from the purely rationalist approach presented in chapter 2. The concept of proximity provides an intuitive tool for the inclusion of geographical as well as cultural-cognitive aspects of organizational change. As such, the proximity approach follows the tradition of environmental sociology founded on the assertion that biophysical factors need to be taken into account in the explanation of social outcomes. This argument, as intuitive as it might seem today, is in stark contrast to much of classical sociology, e.g. Durkheim's, notion that social phenomena could and should only be explained by social facts. Just as environmental sociology struggles with the incorporation of two fundamentally opposing paradigms, an embeddedness or constructivist approach versus a rationalist approach, the proximity framework aims to incorporate these two conflicting views of behavior of social actors. I argue that the value of the proximity approach lies in combining the two as complements – the way in which they have been used in this dissertation: this is where I see the great strength of the proximity framework for the study of coupled systems.

### *How adaptive a response?*

All chapters could be used to support the claim that adaptive social response in the Mississippi River Basin farming sector is weak at best. However, aside from the successful mobilization of resources to resist institutional change, as shown in chapter 3, hot spots of innovation do exist. This observation is in line with traditional notions of proximity effects. The presence of a variety of public, industrial and environmental organizations appears to play a crucial role in fostering organizational innovation. While some may balk at the difficulty of navigating an actor-rich and diverse organizational landscape, according to proximity theory such conditions provide an ideal ground for the cross-fertilization of thought and experimentation across different types of organization. The findings of this dissertation support this claim.

The findings of chapter 3, to do with clear learning effects in the organizational field, may appear to be in contrast to the propositions and findings of chapter 4, which is highly critical of the prospect of learning for change in existing organizations. However, as argued throughout chapter 4, organizational learning and organizational turnover are interdependent. Thus, the findings in chapter 3 on favorable conditions for organizational learning lend additional support to the tentative conclusions arrived at in chapter 4: As the density of organizations that support agro-ecological practices in their work and mission increases, they raise legitimacy that facilitates the emergence of more of their kind. Secondly, there might be indications that ideas do spill over and become more salient, as the example of the increasing prominence of orientating towards cover-cropping in chapters 2 and 4 shows. Future research could serve to substantiate these observations.

Currently, switching to prevention-oriented practices is, as would be argued in resource-based theories, fraught with costs and risks for individual farmers and the organizations whose constituency they are, to the point that they inhibit exploration of these opportunities. This would make it all the more important that a safe trial space be created for farmers to test the practices under a variety of biophysical, social and economic conditions. These conditions can only be created at the level of the organizational field, or broader, the state or nation. And, as the findings suggest, it is only with the help of new players on the playing field that this

testing can occur. Lending support to emergent actors therefore seems a promising strategy for researchers, managers and politicians to further ecological transformation.

### ***Limitations and future research***

#### *Coupled systems research and data availability*

Given the initial question, how scholarly research can improve social adaptation to ecological risks, one of the key conclusions of chapter 2 is that coupled systems research needs coupled research teams. In this connection it is important to stress that it is not always necessary to have the complete expertise in-house, that is, within the scholar or research team studying social-ecological adaptation. As described in chapter 2, if systematic records of stream water quality et cetera existed, these could be used to measure the success of social and political reform. Monitoring and providing data for reality checks is therefore a key role for public agencies in the future. This would mean reversing the trend towards cutting back on monitoring, such as in the case of stream monitoring stations.

Arguably, the work presented here is an on-the-ground reality check of social phenomena, not ecological ones. Despite the fact that the chapters of this dissertation rely on agro-ecological critiques formalized as a typology in close exchange with natural scientists, the measures used – cultural-cognitive proximity, resources mobilized and programs implemented – still apply to the social sphere only; no assessments of soil health or nitrogen leaching as a consequence of the resource allocation in organizations were made. As a result, future research should make it more central to incorporate ecological measures into the study of social reform for sustainability. Proxies, as have been used in this dissertation, e.g. organizational programs, could be misleading, since they may in fact tend to introduce a bias towards finding evidence in favor of shifting to a greener agriculture, as is unfortunately shown in the case at hand. Such findings are in contrast to publicly funded monitoring efforts. A recent USNRCS (2010) report showed that the on-the-ground implementation of ecological practices is conspicuously missing in those regions that are among the biggest contributors to pollution.



### *Symbolic action*

This dissertation was premised on the notion that investments are real, that is to say that they are made to achieve their stated objectives. The claim was a priori considered to be centered on achieving ecological improvements and maintaining agricultural production. This purely rationalistic account was opened up for contestation in chapter 3, where attention to cognitive proximity introduced non-rationalistic elements of explanation. However, this attempt to account for the logic of embeddedness in explaining social behavior still proved incomplete. Gaps in explanation remained, perhaps not surprisingly, after studying resource quantity and quality, as well as geographical and cultural-cognitive variation. Here, the in-depth understanding of a case at hand served to highlight the limits of the material resource approach. What an organizational resource can achieve in a given context depends largely on how the resource is viewed and used. For example, hiring an environmental expert might well constitute a resource investment in response to changed demands for environmental accountability (Scott 2002). However, assuming that this action alone will automatically improve the environmental performance of an organization is too simple a causal argument; it ignores the possibility that this person was hired only to keep up the appearance that the organization under scrutiny takes the external accountability demands seriously, while de facto this person may do nothing to actually change organizational environmental outputs for the better.

This argument is supported by Frickel and Davidson's (2004) observation that environmental improvements are often undertaken in efforts to maintain political legitimacy rather than addressing the root causes of environmental degradation. Actual environmental improvements rarely result from symbolic actions which are aimed at preventing political conflict rather than solving environmental problems (Edelman 1964; Hajer 1996; Frickel and Davidson 2004). Symbolic actions are thus unlikely to support the actual reforms necessary to achieve sustainability (Frickel and Davidson 2004). Such "symbolic or low-cost compliance" can occur when external pressures are low (Strang and Jung 2005: 309). Based on the findings of this dissertation, the presumed multiple and layered institutional pressures on organizations exist, but are weak.

Some qualitative findings from the interviews conducted further support this argument. For example, several respondents who were considered environmental experts in their organizational fields denied the role of agriculture in the formation of Gulf hypoxia outright. Moreover, organizational mission goals and respondent orientation and behavior showed discrepancies. For example, one farmer program was instituted “as an answer to a problem” – not to a pollution problem, as one might assume from the program’s mission and materials, but to a regulatory problem, specifically to avoid regulation in the form of a “mandatory program”. For the respondent, the question was not whether a program could be instituted that could improve certain ecological conditions, but rather, that a program was needed “that the EPA [Environmental Protection Agency]... will accept and work with us on”. Here, the struggle for legitimacy, and nothing else, was the guiding principle behind the creation of this program. It is in the realm of such institutional processes and frameworks that the limits of a quantitative material resource assessment lie.

Quantitative analysis without regard for the voices and behavior of those involved in driving – or resisting – social-ecological adaptation can lead to incomplete explanations. Therefore, the findings throughout, especially in chapter 3 and chapter 4, are rounded out by observations and comments made during the interview phase. Certainly, such commitment to detailed understanding could go much further, and as others have stressed, could lead to a much better understanding of the opportunities and constraints of social-ecological adaptation. In practice this would mean research in the form of detailed, open-ended questioning, and expansive time and space for respondent narratives, participatory and observational or ethnographical research, “not by providing the answers . . . but by raising some relevant questions.” (Castells 1996: 4)

### ***Conclusion***

For practical purposes, a superficial assessment of the investments made in ecological reform presented in chapters 2, 3, and 4 can lead one to conclude that ecological reform is well underway in many instances. The public debate about sustainability permeates all spheres of our lives, and as this and other research has shown, nominal investments are considerable. However, disaggregating these investments by space, time and topic

shows that responses at all levels of social organization, nation, state, and organizational fields are poorly targeted, weakly ecological, and often outright symbolic, created to meet legitimacy challenges, not environmental goals.

Theoretically, the studies presented share some key elements: all make the point that in order to understand social-ecological adaptation, the level of analysis chosen plays a critical role. The papers presented illustrate the profound systemic effects that are at work at the level of constellations of organizations joined by shared representations, geographical regions, or time of founding. These effects structure the opportunities for individuals and individual organizations to pursue or hinder ecological reform. To date, a strong focus on concepts of individual agency and individual as well as organizational learning severely limits researchers', managers', and policy makers' ability to understand and manage these systemic aspects of ecological reform. The findings in chapter 4 stress that learning is difficult and incomplete. Research, management and policy of natural resources would therefore benefit from a strong complementary focus on organizational field level inquiries into the processes that structure the opportunities and constraints of the individuals so extensively studied. Attending to changes at the level of organizational populations as a complement to learning at the level of the individual organization can advance a political and scholarly debate about the greening of agriculture.

All findings presented depend on the operationalization of rather vague theories of coupled social-ecological systems. As such, all papers presented in this dissertation aim to provide the necessary frames and mid-range variables that can serve to understand social-ecological processes in more than one setting. Concepts such as the social-ecological interface, targeting, proximity or organizational age need to be evaluated and interpreted in individual cases, but they are sufficiently flexible to serve as tools with which to explain patterns of social change for a broad range of cases and topics. As such, the frames and variables presented help to ascertain whether, and to what extent, adaptive social-ecological coupling is manifested in a particular setting and how

institutional, organizational, and geographical contexts constrain and enable adaptation to sustainability demands.

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## APPENDIX

### INTERVIEW GUIDE

#### *About your organization*

1. Please, define your organization/unit.
2. When was your organization founded?
3. How many employees does your organization have?
4. How many members does your organization have, if applicable?
5. How is your organization structured?
6. What is your position in the organization?
7. Are you in a position to influence farmer behavior
8. In influencing farming practices, what other organizations/groups/individuals – if any – form a link between your organization and farmers.

#### *Nutrient management relevant programming*

9. Can you give me an overview of what your organization does.
  - Anticipate changes in programming?
10. What budget does your organization have for these programs?
  - Anticipate changes in budget?
11. What are your organizations core competencies with respect to nutrient management practices, what is your organization good at?
  - What are your products/services?
  - Who are your clients?
12. What budget is dedicated to nutrient management?
  - Anticipate changes in budget?

#### **Your organization's competencies**

A) People, training and knowledge

13. Number of full time staff in nutrient management relevant programming
14. Highest educational degrees of these staff?
15. Years of experience of these staff in programming
16. Plans to hire
17. What degrees planned to hire
18. What experience levels planned to hire
19. Special training relevant to programming?
20. Special training planned?

B) Internal structure

21. Do you have a mission statement? Can you share it?
22. Do you plan one, have a draft? Plan to change it?
23. Do you keep records on programming?
24. Do you plan to keep records in future? Change record keeping?
25. What are your objectives with above programming?
26. Do you plan on new objectives? Change objectives?
27. How do you improve programming?
28. Plans to change improvement system, if any? Introduce one?
29. What constrains your organization from within to achieve these objectives?
30. Do you expect change in internal constraints?

C) External relations

31. What linkages do you have to external actors relevant to programming?
  - Do you have contacts outside of your state?
  - Do you have regional/national working contacts, e.g. in DC?
32. How do you see these links develop/change in the future?

33. If you think of your contact list, are some constraining you in your work? Are there others not yet listed which constrain your work? How?
34. How do you see these relationships develop/change in the future?

***Organizational history***

35. Tell me about the history of nutrient management issues in your organization. - Restructuring, foundings, deaths, changes in form, triggers? People? Budget?

***Views on nutrient management***

36. What farm nutrient management practices do you consider having the most potential to improve water quality?
37. Do you consider different practices most promising for different regions of the MRB?

***Referrals and open questions***

38. Who else do you think I should talk to?
39. Is there anything that you think we should have covered but didn't?
40. Any comments you have questions, approach, anything else you want to let me know?

**Thank you very much!**